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Mathematics Learning Support and Dyslexia in Higher Education

by
Glynis Perkin

A Doctoral Thesis
Submitted in partial fulfilment of the requirements for the award of
Doctor of Philosophy of Loughborough University
April 2007

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THESIS
CONTAINS
CD/
Education, education and education

1996

Rt. Hon. Tony Blair
Acknowledgements

To my Supervisor, Dr. Tony Croft, who supported me admirably for three years, embraced this work with endless patience and enthusiasm and instilled in me the importance of rigour when undertaking academic research, I extend my unreserved thanks and admiration.

I would like to acknowledge those staff, too numerous to mention individually, in the School of Mathematics, the English Language Study Unit, the Disabilities and Additional Needs Service and the Library, who have helped and offered advice throughout the duration of this work. A special thank you is extended to Clare Trott from the Mathematics Education Centre and Jacqueline Szumko from the English Language Study Unit. Not only have they shared their knowledge and understanding of dyslexia with me, but also encouraged and supported me during the last three years.

Finally, I would like to thank all the students who participated in this research, without whom this work would not have been possible.
Publications

Journal Articles

Published


In Press


Perkin, G. & Croft, A.C. The Dyslexic Student and Mathematics in Higher Education. *Dyslexia*.


Conference Papers

Published


**Presentations & Workshops**

At events organised by the Dyscalculia and Dyslexia Interest Group (DDIG), (http://ddig.lboro.ac.uk).


Abstract

This research identifies, through an extensive series of exploratory and explanatory case studies, the mathematical difficulties that might be encountered by dyslexic engineering students. It details support mechanisms that may be put in place to help these students reach their full potential and makes suggestions for the introduction of measures at institutional level to ensure compliance with current legislation. This is an area, identified from the literature search, that has not, until now, been the focus of any substantial research activity and thus the findings form an original and significant contribution to knowledge in this field. The findings are not only intrinsically interesting but will also be of use to practitioners of mathematics, support staff, staff developers and policy makers in higher education.

A literature review gives historical background on the development of education in general, and mathematics in particular, in the UK. The main theories and problems associated with developmental dyslexia are also given. Surveys were undertaken to determine the extent of mathematics learning support in UK universities and also to determine the extent of the provision of mathematics support to dyslexic students. Using case study research and by providing one-to-one mathematics support, the difficulties encountered by dyslexic students were investigated. Related work is an exploratory study into the use of different media combinations in Computer Assisted Assessment. Additionally, an in-depth case study of the Mathematics Learning Support Centre at Loughborough University has been undertaken and is reported in detail with recommendations for changes suggested.

The results of this research show that mathematics learning support is widespread and often essential to bridge the gap between school mathematics and university level mathematics but specialist mathematical support for dyslexic students is rarely available. It is determined that dyslexic students can be impeded in their learning and understanding of mathematics as a direct result of their dyslexia. Recommendations for further study in some areas and future lines of inquiry in others are suggested.

Keywords: Higher Education, mathematics support, dyslexia and mathematics, dyslexia and engineering, case study research, student experience.
Background of the Researcher

The words of Tony Blair were particularly inspiring and highly pertinent to the author of this thesis, who had, in 1994, as a result of the closure of a large pharmaceutical company in Loughborough, been made redundant after 20 years service. With the continuing decline in manufacturing during the 1990’s and an increasing feeling of vulnerability linked to future employability it was the statement “Education, education and education” that prompted consideration of reading for a degree in mathematics.

Just prior to obtaining two General Certificate of Education Advanced Level, grade A passes in Mathematics and Further Mathematics through evening class study, redundancy was again encountered due to closure of the Loughborough based printers and publishers of books for children.

The author then entered Loughborough University in 1999, at the age of 44, to read for a 4-year Master of Mathematics degree. During the first year of study, the Mathematics Learning Support Centre proved to be of invaluable assistance, helping immensely with gaps in prior knowledge and understanding, with difficult questions on tutorial sheets and in the provision of gentle guidance on the use of mathematical texts all of which promoted and assisted the adjustment to self-study. Interest in the provision of mathematics support and its efficacy remained throughout subsequent undergraduate years. After graduating, with a Second Class Honours Upper Division classification the author was accepted as a Ph.D student in the Mathematics Education Centre at Loughborough University.
<table>
<thead>
<tr>
<th>CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title Page</td>
</tr>
<tr>
<td>Declaration</td>
</tr>
<tr>
<td>Frontispiece</td>
</tr>
<tr>
<td>Acknowledgements</td>
</tr>
<tr>
<td>Publications</td>
</tr>
<tr>
<td>Abstract</td>
</tr>
<tr>
<td>Background of the Researcher</td>
</tr>
<tr>
<td>Chapter Listing</td>
</tr>
<tr>
<td>References</td>
</tr>
<tr>
<td>List of Figures</td>
</tr>
<tr>
<td>List of Tables</td>
</tr>
<tr>
<td>Appendices</td>
</tr>
<tr>
<td>Glossary of Abbreviations</td>
</tr>
</tbody>
</table>

**Chapter Listing**

<table>
<thead>
<tr>
<th>I. Introduction:</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Background to the Research</td>
<td>1</td>
</tr>
<tr>
<td>1.2 The Field of the Research</td>
<td>5</td>
</tr>
<tr>
<td>1.3 The Research Questions</td>
<td>8</td>
</tr>
<tr>
<td>1.4 Training Undertaken by the Researcher</td>
<td>9</td>
</tr>
<tr>
<td>1.5 Ethical Issues</td>
<td>9</td>
</tr>
<tr>
<td>1.6 Dissemination</td>
<td>12</td>
</tr>
<tr>
<td>1.7 Overview of the Thesis</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Historical Perspective and Literature Review:</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction – a general overview of the chapter</td>
<td>18</td>
</tr>
<tr>
<td>2.2 The Evolution of the Educational System in the UK</td>
<td>22</td>
</tr>
<tr>
<td>2.3 The Introduction of GCSE - Mathematics Education from 1986</td>
<td>22</td>
</tr>
<tr>
<td>2.4 Dyslexia and Mathematics</td>
<td>24</td>
</tr>
</tbody>
</table>
III. Dyslexia:

3.1 Historical Overview of the Developing Concept of Dyslexia 42
3.2 Levels of Dyslexia 49
3.3 Theories of Dyslexia 50
  3.3.1 The Phonological Deficit 51
    3.3.1.1 Phonological Awareness and Verbal Memory 53
  3.3.2 The Magnocellular Deficit 55
    3.3.2.1 Visual Sensitivity and Coloured Filters 58
    3.3.2.2 Auditory Problems 59
  3.3.3 The Cerebellar Deficit 60
    3.3.3.1 Motor-skills 63
3.4 Summary of the Theories of Dyslexia 64
3.5 Statistics for Dyslexia in Higher Education 66
3.6 Dyslexia Diagnosis and Support at Loughborough University 67
  3.6.1 Dyslexia Diagnosis at Loughborough University 67
  3.6.2 Dyslexia Support at Loughborough University 68
    3.6.2.1 Choice of Font 70
3.7 Dyslexia Records at Loughborough University 71
  3.7.1 The Data Collection 71
  3.7.2 Results of the Data Collection 72
3.8 Summary of Dyslexia in Higher Education 73

IV. Research Methods:

4.1 Case Study as a Research Method 74
4.2 The Exploratory Case Studies 75
4.3 Case Studies of the Students Receiving One-to-One Support 77
4.4 The Explanatory Case Studies 78
4.5 The Loughborough MLSC Study 80
4.6 Summary of the Cases Studies 85
5.7 Triangulation of Data
5.8 Summary of the Findings
5.9 Conclusion

6.1 Case Study 1: Patrick
   6.1.1 Discussions with Patrick
   6.1.2 Report from the Author of this Thesis
   6.1.3 Report from the Educational Psychologist
   6.1.4 Working with Patrick
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2</td>
<td>Case Study 2: Peter</td>
<td>145</td>
</tr>
<tr>
<td>6.2.1</td>
<td>Interview with Peter</td>
<td>145</td>
</tr>
<tr>
<td>6.2.2</td>
<td>Report from the Mathematics Learning Support Centre</td>
<td>150</td>
</tr>
<tr>
<td>6.2.3</td>
<td>Report from the Educational Psychologist</td>
<td>151</td>
</tr>
<tr>
<td>6.2.4</td>
<td>Working with Peter</td>
<td>151</td>
</tr>
<tr>
<td>6.3</td>
<td>Working with Russ</td>
<td>157</td>
</tr>
<tr>
<td>6.4</td>
<td>Triangulation of Date</td>
<td>158</td>
</tr>
<tr>
<td>6.5</td>
<td>Findings from the One-to-One Support Case Studies</td>
<td>159</td>
</tr>
<tr>
<td>6.6</td>
<td>Conclusion</td>
<td>160</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VII. The Explanatory Case Studies:</th>
<th>163</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Case Study 1: Edward</td>
<td>167</td>
</tr>
<tr>
<td>7.1.1 Interview with Edward</td>
<td>167</td>
</tr>
<tr>
<td>7.1.2 Report from the English Language Study Unit</td>
<td>170</td>
</tr>
<tr>
<td>7.1.3 Report from the Mathematics Learning Support Centre</td>
<td>170</td>
</tr>
<tr>
<td>7.2 Case Study 2: Phyllis</td>
<td>171</td>
</tr>
<tr>
<td>7.2.1 Interview with Phyllis</td>
<td>171</td>
</tr>
<tr>
<td>7.2.2 Report from the English Language Study Unit</td>
<td>173</td>
</tr>
<tr>
<td>7.3 Case Study 3: Stuart</td>
<td>174</td>
</tr>
<tr>
<td>7.3.1 Interview with Stuart</td>
<td>174</td>
</tr>
<tr>
<td>7.3.2 Report from the English Language Study Unit</td>
<td>181</td>
</tr>
<tr>
<td>7.3.3 Report from the Mathematics Learning Support Centre</td>
<td>181</td>
</tr>
<tr>
<td>7.3.4 Report from the Educational Psychologist</td>
<td>182</td>
</tr>
<tr>
<td>7.4 Case Study 4: Alan</td>
<td>183</td>
</tr>
<tr>
<td>7.4.1 Interview with Alan</td>
<td>183</td>
</tr>
<tr>
<td>7.4.2 Report from the English Language Study Unit</td>
<td>185</td>
</tr>
<tr>
<td>7.4.3 Report from the Educational Psychologist</td>
<td>185</td>
</tr>
<tr>
<td>7.5 Case Study 5: Daniel</td>
<td>186</td>
</tr>
<tr>
<td>7.5.1 Interview with Daniel</td>
<td>186</td>
</tr>
<tr>
<td>7.5.2 Report from the Mathematics Learning Support Centre</td>
<td>188</td>
</tr>
<tr>
<td>7.5.3 Report from the Educational Psychologist</td>
<td>188</td>
</tr>
<tr>
<td>7.6 Case Study 6: Chris</td>
<td>189</td>
</tr>
<tr>
<td>7.6.1 Interview with Chris</td>
<td>189</td>
</tr>
<tr>
<td>7.6.2 Report from the Mathematics Learning Support Centre</td>
<td>191</td>
</tr>
</tbody>
</table>
7.7 Case Study 7: Anthony 191
  7.7.1 Interview with Anthony 191
  7.7.2 Report from the Mathematics Learning Support Centre 194
  7.7.3 Report from the Educational Psychologist 194

7.8 Case Study 8: James 194
  7.8.1 Interview with James 194
  7.8.2 Report from the Mathematics Learning Support Centre 196
  7.8.3 Report from the Educational Psychologist 197

7.9 Case Study 9: Jack 197
  7.9.1 Interview with Jack 198
  7.9.2 Report from the Author of this Thesis 200
  7.9.3 Report from the Educational Psychologist 201

7.10 Case Study 10: Bob 202
  7.10.1 Interview with Bob 202
  7.10.2 Report from the Mathematics Learning Support Centre 204
  7.10.3 Report from the Educational Psychologist 204

7.11 Case Study 11: Joseph 205
  7.11.1 Interview with Joseph 205
  7.11.2 Report from the Mathematics Learning Support Centre 207

7.12 Case Study 12: Lee 208
  7.12.1 Interview with Lee 208
  7.12.2 Report from the Mathematics Learning Support Centre 211
  7.12.3 Report from the Educational Psychologist 211

7.13 Triangulation of Data 211

7.14 The Non-Dyslexic Students 212
  7.14.1 Interview 1: Dan 212
  7.14.2 Interview 2: Trev 212
  7.14.3 Interview 3: Dev 214
  7.14.4 Interview 4: Gary 215
  7.14.5 Interview 5: Bella 215
  7.14.6 Interview 6: Wayne 216
  7.14.7 Interview 7: Rachel 216
  7.14.8 Interview 8: Nico 217
  7.14.9 Interview 9: Andrew 218
9.4 Mathematics Support for Dyslexic Students in HE

9.4.1 Procedure for the Survey

9.4.2 Response Levels by University Category

9.4.3 Results of the Survey

9.4.4 Details by University Category

9.4.4.1 'Russell Group' Universities

9.4.4.2 'Red Brick' Universities

9.4.4.3 'Old' Universities

9.4.4.4 'New Universities

9.5 Conclusion

X. Loughborough Mathematics Learning Support Centre

10.1 History of the Mathematics Learning Support Centre

10.1.1 Interview with Mr. Geoff Simpson

10.1.2 Interview with Professor Clive Pugh

10.2 The Mathematics Education Centre

10.3 Observations in the Mathematics Learning Support Centre

10.3.1 Difficulties Related to Prior Mathematical Knowledge

10.3.2 General Mathematical Difficulties

10.3.3 Staff Working in the Mathematics Learning Support Centre

10.4 Survey of the Mathematics Learning Support Centre

10.4.1 Background to the Survey

10.4.2 Preliminary Analysis of the Data

10.4.3 Analysis

10.5 Results of the Selected Questions

10.5.1 Questions to Determine the Effectiveness of the MLSC

10.5.2 Questions to Determine the Effectiveness of the MLSC for Dyslexic Students

10.5.3 Questions to Determine the Necessity of the MLSC

10.6 Conclusion and Recommendations
# Conclusion

11.1 Summary of the Research Findings 322

11.2 The Research Questions Revisited 330

11.2.1 Research Question 1 330

11.2.2 Research Question 2 331

11.2.3 Research Question 3 332

11.2.4 Research Question 4 332

11.3 Recommendations 333

11.4 Suggestions for Future Research 335

## References

## Illustrations

### List of Figures:

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landmarks in the Evolution of Education</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Differences between Dyslexia and Dyscalculia</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>Areas of the Brain 1</td>
<td>43</td>
</tr>
<tr>
<td>4</td>
<td>Areas of the Brain 2</td>
<td>44</td>
</tr>
<tr>
<td>5</td>
<td>A Causal Model of Dyslexia as a result of Cerebellar Abnormality</td>
<td>49</td>
</tr>
<tr>
<td>6</td>
<td>A General Magnocellular Theory of Dyslexia</td>
<td>56</td>
</tr>
<tr>
<td>7</td>
<td>An Ontogenetic Causal Chain</td>
<td>62</td>
</tr>
<tr>
<td>8</td>
<td>Patrick’s Mind Map for Advanced Algebra</td>
<td>128</td>
</tr>
<tr>
<td>9</td>
<td>Patrick’s Mind Map for Probability</td>
<td>129</td>
</tr>
<tr>
<td>10</td>
<td>Patrick’s Mind Map for Differentiation</td>
<td>130</td>
</tr>
<tr>
<td>11</td>
<td>A Memory Aid for Sine and Cosine Functions</td>
<td>140</td>
</tr>
<tr>
<td>12</td>
<td>Model Answer to a Lagrange Multiplier Question</td>
<td>143</td>
</tr>
<tr>
<td>13</td>
<td>A Memory Aid for Even and Odd Fourier Co-efficients</td>
<td>154</td>
</tr>
<tr>
<td>14</td>
<td>Graphical Representation Required by Stuart</td>
<td>177</td>
</tr>
<tr>
<td>15</td>
<td>Matrix Representation Required by Stuart</td>
<td>178</td>
</tr>
<tr>
<td>16</td>
<td>Further Graphical Representation Required by Stuart</td>
<td>178</td>
</tr>
<tr>
<td>17</td>
<td>Text Taken from a Poster Entitled 'A different Kind of Library' displayed in De Montfort University Maths Centre</td>
<td>264</td>
</tr>
</tbody>
</table>
Figure 18  Text Taken from a Poster Entitled ‘Cheating’ displayed in De Montfort University Maths Centre 264
Figure 19  Most Frequent Reasons for Using the MLSC 292
Figure 20  Students (by age) – most frequent reasons for using the MLSC 293
Figure 21  Reasons for Students’ Seeking Help with Mathematics 312
Figure 22  Reasons (by student age) for Students Seeking Help with Mathematics 313

List of Tables:

Table 1  Mathematics A Level Numbers and % of Entries 20
Table 2  No. of Dyslexic Engineering Students at Loughborough University 72
Table 3  Students Participating in the Exploratory Case Studies 87
Table 4  Tom’s Cluster Group Scores from the Educational Psychologist 95
Table 5  Robert’s Cluster Group Scores from the Educational Psychologist 100
Table 6  Ryan’s Cluster Group Scores from the Educational Psychologist 104
Table 7  Otto’s Cluster Group Scores from the Educational Psychologist 108
Table 8  Keith’s Cluster Group Scores from the Educational Psychologist 113
Table 9  Students in the Exploratory Studies - Collated Cluster Group Scores 118
Table 10  Difficulties Experienced by Students in the Exploratory Studies 118
Table 11  Patrick’s Cluster Group Scores from the Educational Psychologist 132
Table 12  Peter’s Cluster Group Scores from the Educational Psychologist 151
Table 13  Dyslexic Students Participating in the Explanatory Studies 166
Table 14  The Control Group of Non-Dyslexic Students 167
Table 15  Stuart’s Cluster Group Scores from the Educational Psychologist 182
Table 16  Alan’s Cluster Group Scores from the Educational Psychologist 186
Table 17  Daniel’s Cluster Group Scores from the Educational Psychologist 189
Table 18  James’ Cluster Group Scores from the Educational Psychologist 197
Table 19  Jack’s Cluster Group Scores from the Educational Psychologist 201
Table 20  Bob’s Cluster Group Scores from the Educational Psychologist 204
Table 21  Difficulties with Note Taking 221
Table 22  Difficulties with Multi-Stage Mathematical Operations 222
Table 23  Visual Difficulties 223
Table 24  Difficulties with Descriptive Text 223
Table 25  Recall of Notation and Formulae 224
Table 26 Tutorial Support is Inadequate
Table 27 Drop-In Support at the MLSC is Inadequate
Table 28 Some Methods of Mathematical Delivery and Assessment are Unfair
Table 29 Use of Mind Maps for Mathematics
Table 30 Understand Material but Obtain Incorrect Answers
Table 31 Findings for Each of the Hypotheses
Table 32 Number of Students in Each Version Who Gave Correct Answers
Table 33 Analysis of the Students' Paper Based Working
Table 34 Number who Failed to Recognise \( \cos(n \pi) \) is a Constant (question 1) and Failed to Split the Integral (question 3)
Table 35 Average Score from Manual Marking of the Scripts
Table 36 Mathematics Learning Support - response levels by university category
Table 37 Availability of Mathematics Learning Support - numbers by university category
Table 38 Mathematics Learning Support in the 'Russell Group' Universities
Table 39 Mathematics Learning Support in the 'Red Brick' Universities
Table 40 Mathematics Learning Support in the 'Old' Universities
Table 41 Mathematics Learning Support in the 'New' Universities
Table 42 One-to-One Mathematics Learning Support for Dyslexic Students - response levels by university category
Table 43 Availability of One-to-One Mathematics Learning Support for Students with Dyslexia - numbers by university category
Table 44 Proportion of Time Spent in the MLSC for Coursework and Examinations
Table 45 Recognised as, or are, Frequent Users of the MLSC
Table 46 Progress of Students who Frequently Attend the MLSC
Table 47 Awareness of the Lunchtime Support Sessions
Table 48 Awareness of the Lunchtime Support Sessions (staff by age)
Table 49 Staff Use of Resources in the MLSC
Table 50 Staff Use of Expertise in the MLSC
Table 51 Staff Awareness of Specialist Help in the MLSC
Table 52 Staff Awareness of Events Organised by the MLSC
Table 53 Student Usage of Handouts in the MLSC
Table 54 Students' Views on the Handouts in the MLSC
Table 55 Students Requiring Handouts for Additional Topics
Table 56 Are Staff in the MLSC able to assist Students?
Table 57 Proportion of Staff in the MLSC Considered by Students to be Helpful
Table 58 Percentage of Staff who have Received Dyslexia Related Training
Table 59 Percentage of Staff who Recognised Students who might be Dyslexic
Table 60 Percentage of Staff who Suspected Dyslexia Amongst Students they Encountered in the MLSC
Table 61 Does the MLSC Meet the Needs of Dyslexic Students?
Table 62 Undergraduate Courses Start at a Higher Level than Students' Mathematical Backgrounds Have Prepared Them For
Table 63 Students by Age - undergraduate courses start at a higher level than their mathematical backgrounds have prepared them for
Table 64 Staff Opinion of the Proportion of Students Encountered in Tutorials and Tutee Groups who should have been Admitted onto a Degree Programme
Table 65 Staff Opinion of the Proportion of Students Encountered in the MLSC who should have been admitted onto a Degree Programme
Table 66 Mathematical Background Related to Impact on Understanding
Table 67 Percentage of Students able to Understand Initial Explanation
Table 68 Is there, on academic grounds, a need for the MLSC?
Table 69 Is there, on economic grounds, a need for the MLSC?

Appendices (located on the CD):

Appendix A: The Exploratory Case Studies
   A.1 Student Consent Form
   A.2 Research Design
   A.3 Protocol
      A.3.1 Introduction to & Purpose of the Exploratory Case Studies
      A.3.2 Data Collection Procedures
      A.3.3 The Exploratory Case Study Question
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.3.4 The Exploratory Case Study Report</td>
<td>352</td>
</tr>
<tr>
<td>A.4 Criteria for Judging the Quality of the Research Design</td>
<td>352</td>
</tr>
<tr>
<td>A.4.1 Construct Validity</td>
<td>352</td>
</tr>
<tr>
<td>A.4.2 External Validity</td>
<td>353</td>
</tr>
<tr>
<td>A.4.3 Reliability</td>
<td>353</td>
</tr>
<tr>
<td>A.5 Interview Questions</td>
<td>353</td>
</tr>
<tr>
<td>A.5.1 Initial Interview Questions</td>
<td>353</td>
</tr>
<tr>
<td>A.5.2 Additional Interview Questions – asked at the 2nd interview</td>
<td>354</td>
</tr>
</tbody>
</table>

Appendix B: The ‘One-to-One’ Case Studies

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.1 Student Consent Form</td>
<td>355</td>
</tr>
<tr>
<td>B.2 Research Design</td>
<td>355</td>
</tr>
<tr>
<td>B.3 Protocol</td>
<td>355</td>
</tr>
<tr>
<td>B.3.1 Introduction to and Purpose of the ‘One-to-One’ Case Studies</td>
<td>355</td>
</tr>
<tr>
<td>B.3.2 Data Collection Procedures</td>
<td>356</td>
</tr>
<tr>
<td>B.3.3 The ‘One-to-One’ Case Study Questions</td>
<td>357</td>
</tr>
<tr>
<td>B.3.4 The ‘One-to-One’ Case Study Report</td>
<td>357</td>
</tr>
<tr>
<td>B.4 Criteria for Judging the Quality of the Research Design</td>
<td>358</td>
</tr>
<tr>
<td>B.4.1 Construct Validity</td>
<td>358</td>
</tr>
<tr>
<td>B.4.2 Internal Validity</td>
<td>358</td>
</tr>
<tr>
<td>B.4.3 External Validity</td>
<td>358</td>
</tr>
<tr>
<td>B.4.4 Reliability</td>
<td>358</td>
</tr>
<tr>
<td>B.5 Interview Questions</td>
<td>359</td>
</tr>
</tbody>
</table>

Appendix C: The Explanatory Case Studies

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.1 Student Consent Form</td>
<td>360</td>
</tr>
<tr>
<td>C.2 Student Payment Form</td>
<td>360</td>
</tr>
<tr>
<td>C.3 Research Design</td>
<td>361</td>
</tr>
<tr>
<td>C.4 Protocol</td>
<td>362</td>
</tr>
<tr>
<td>C.4.1 Introduction to and Purpose of the Explanatory Case Studies</td>
<td>362</td>
</tr>
<tr>
<td>C.4.2 Data Collection Procedures</td>
<td>362</td>
</tr>
<tr>
<td>C.4.3 The Explanatory Case Study Questions</td>
<td>363</td>
</tr>
<tr>
<td>C.4.4 The Explanatory Case Study Report</td>
<td>363</td>
</tr>
<tr>
<td>C.5 Criteria for Judging the Quality of the Research Design</td>
<td>364</td>
</tr>
</tbody>
</table>
C.5.1 Construct Validity 364
C.5.2 Internal Validity 364
C.5.3 External Validity 364
C.5.4 Reliability 365

C.6 Interview Questions 365

Appendix D: Trial of CAA Material 367
D.1 Student Payment Form 367
D.2 Personal Details 368
D.3 Post-test Questionnaire 369

Appendix E: Mathematics Support in Higher Education 373
E.1 E-mail sent to the Universities Selected for the Survey 373
E.2 Consent Form for the Universities that were Visited 374
E.3 Questions Posed to the Universities that were Visited 374
E.4 E-mail sent to the Universities who provided Mathematics Support 380

Appendix F: The Mathematics Learning Support Centre Case Study 381
F.1 Research Design 381
F.2 Protocol 382
  F.2.1 Introduction to and Purpose of the MLSC Case Study 382
  F.2.2 Data Collection Procedures 383
  F.2.3 The MLSC Case Study Questions 383
  F.2.4 The MLSC Case Study Report 383
F.3 Criteria for Judging the Quality of the Research Design 384
  F.3.1 Construct Validity 384
  F.3.2 Internal Validity 384
  F.3.3 External Validity 384
  F.3.4 Reliability 384
F.4 Letter Accompanying the Staff Census Form 385
F.5 The Staff Census Form 386
F.6 The Student Questionnaire 403
Appendix G: Historical Perspective

G.1 Elementary Education in the 18th Century
G.2 Elementary Education in 19th Century England
G.3 Secondary Education in 19th Century England
G.4 Elementary Education in 20th Century England
G.5 Secondary Education in 20th Century England
G.6 Higher Education
G.7 Mathematics Education Since 1986
  G.7.1 GCSE Mathematics
    G.7.1.1 Content
    G.7.1.2 The 3-tier System
    G.7.1.3 Issues and Worries
  G.7.2 GCE A Level Mathematics
    G.7.2.1 Syllabi - Changes and Content
    G.7.2.2 Uptake and Pass Rates
    G.7.2.3 Issues and Worries
  G.7.3 Mathematics in Higher Education
    G.7.3.1 Reported Difficulties, Findings and Recommendations
    G.7.3.2 The Voice of the Academics
    G.7.3.3 Effects of the Changes in Mathematical Background
    G.7.3.4 Measures Taken by Universities to Address the Problem

Appendix H: Case Study as a Research Method

H.1 The History of Case Study
H.2 When is Case Study a Suitable Method for Research
H.3 What is the Case Study Method
H.4 Strengths and Weaknesses of Case Study
H.5 Types of Case Study
H.6 The Unit of Analysis
H.7 Research Design
H.8 Case Study Protocol
H.9 Data Collection and Triangulation
H.10 Validity and Reliability
H.11 Analysis
### Glossary of Abbreviations

This glossary contains abbreviations that have been used within this thesis.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADD</td>
<td>Attention Deficit Disorder</td>
</tr>
<tr>
<td>ALERT</td>
<td>Accessibility in Learning Environments and Related Technologies</td>
</tr>
<tr>
<td>ARQ</td>
<td>At Risk Quotient</td>
</tr>
<tr>
<td>BDA</td>
<td>British Dyslexia Association</td>
</tr>
<tr>
<td>BEng</td>
<td>Bachelor of Engineering</td>
</tr>
<tr>
<td>BP</td>
<td>British Petroleum</td>
</tr>
<tr>
<td>BSc.</td>
<td>Bachelor of Science</td>
</tr>
<tr>
<td>BTEC</td>
<td>Business and Technology Education Council</td>
</tr>
<tr>
<td>CAA</td>
<td>Computer Assisted Assessment</td>
</tr>
<tr>
<td>CAL</td>
<td>Computer Assisted Learning</td>
</tr>
<tr>
<td>CSE</td>
<td>Certificate of Secondary Education</td>
</tr>
<tr>
<td>DANS</td>
<td>Disabilities and Additional Needs Service</td>
</tr>
<tr>
<td>DAST</td>
<td>Dyslexia Adult Screening Test</td>
</tr>
<tr>
<td>DDIG</td>
<td>Dyscalculia and Dyslexia Interest Group</td>
</tr>
<tr>
<td>DELNI</td>
<td>Department for Employers and Learning, Northern Ireland</td>
</tr>
<tr>
<td>DfES</td>
<td>Department for Education and Skills</td>
</tr>
<tr>
<td>DSA</td>
<td>Disabled Students’ Allowances</td>
</tr>
<tr>
<td>ELSU</td>
<td>English Language Study Unit</td>
</tr>
<tr>
<td>EP</td>
<td>Educational Psychologist</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FDTL4</td>
<td>Phase 4 of the Fund for the Development for Teaching and Learning</td>
</tr>
<tr>
<td>FE</td>
<td>Further Education</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GCE A Level</td>
<td>General Certificate of Education – Advanced Level</td>
</tr>
<tr>
<td>GCE O Level</td>
<td>General Certificate of Education – Ordinary Level</td>
</tr>
<tr>
<td>GCSE</td>
<td>General Certificate of Secondary Education</td>
</tr>
<tr>
<td>GNVQ</td>
<td>General National Vocational Qualification</td>
</tr>
<tr>
<td>HE</td>
<td>Higher Education</td>
</tr>
<tr>
<td>HEA</td>
<td>Higher Education Academy</td>
</tr>
<tr>
<td>HEFCE</td>
<td>Higher Education Funding Council for England</td>
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</tbody>
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xxiv
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEFCW</td>
<td>Higher Education Funding Council for Wales</td>
</tr>
<tr>
<td>HELM</td>
<td>Helping Engineers Learn Mathematics</td>
</tr>
<tr>
<td>HESA</td>
<td>Higher Education Statistics Agency</td>
</tr>
<tr>
<td>HNC</td>
<td>Higher National Certificate</td>
</tr>
<tr>
<td>IMA</td>
<td>Institute of Mathematics and its Applications</td>
</tr>
<tr>
<td>IPTME</td>
<td>Institute of Polymer Technology and Materials Engineering</td>
</tr>
<tr>
<td>IQ</td>
<td>Intelligence Quotient</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>LEA</td>
<td>Local Education Authority</td>
</tr>
<tr>
<td>LMS</td>
<td>London Mathematical Society</td>
</tr>
<tr>
<td>LTSN</td>
<td>Learning and Teaching Support Network</td>
</tr>
<tr>
<td>MEC</td>
<td>Mathematics Education Centre</td>
</tr>
<tr>
<td>MEng</td>
<td>Master of Engineering</td>
</tr>
<tr>
<td>MLSC</td>
<td>The Mathematics Learning Support Centre at Loughborough University</td>
</tr>
<tr>
<td>MSc</td>
<td>Master of Science</td>
</tr>
<tr>
<td>NCA</td>
<td>National Certificate in Agriculture</td>
</tr>
<tr>
<td>NVQ</td>
<td>National Vocational Qualification</td>
</tr>
<tr>
<td>OBE</td>
<td>Order of the British Empire</td>
</tr>
<tr>
<td>OHP</td>
<td>Overhead Projector</td>
</tr>
<tr>
<td>ONC</td>
<td>Ordinary National Certificate</td>
</tr>
<tr>
<td>PE</td>
<td>Physical Education</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Doctor of Philosophy</td>
</tr>
<tr>
<td>QCA</td>
<td>Qualifications and Curriculum Authority</td>
</tr>
<tr>
<td>RSS</td>
<td>Royal Statistical Society</td>
</tr>
<tr>
<td>SENDA</td>
<td>The Special Educational Needs and Disabilities Act</td>
</tr>
<tr>
<td>SHEFC</td>
<td>Scottish Higher Education Funding Council</td>
</tr>
<tr>
<td>SpLD</td>
<td>Specific Learning Difficulty</td>
</tr>
<tr>
<td>SPM</td>
<td>Standard Progressive Matrices test</td>
</tr>
<tr>
<td>SWAN</td>
<td>Students with Additional Needs</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>VLE</td>
<td>Virtual Learning Environment</td>
</tr>
<tr>
<td>WAIS-III</td>
<td>Weschler Adult Intelligence Scale – Third Edition</td>
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This introductory chapter gives the field of this research, the background underpinning the research and the research questions. The training that has been undertaken by the researcher and the consideration that has been given to ethical issues then follows. The chapter culminates with an overview of the thesis, giving a synopsis of each of the chapters contained within it.

1.1 Background to the Research

Many politicians espouse the value of education and none more so than the UK’s Prime Minister, the Rt. Hon. Tony Blair who, in 1996, at the Labour Party Conference announced that he would be focusing his attention on “education, education and education” (The Labour Party, 1996:83).

Taking heed of this call to education were many students with qualifications gained from the mathematics school curriculum of this time; of these, many were to find themselves inadequately prepared for the demands of university level mathematics. This is not surprising given the extensive changes that have taken place in school mathematics education since 1986, not least of which was the introduction of the General Certificate of Secondary Education (GCSE), the modifications that have been made to it and then the ensuing changes that it became essential to make to the General Certificate of Education Advanced Level (GCE A Level) syllabi. These numerous changes have led to adjustments to the content of university courses and there are many arguments (presented and discussed in Chapter II) that suggest there has been a lowering of academic standards.

Prior to these changes, the majority of students who arrived at university to undertake an undergraduate course, containing a significant amount of mathematics, had been well prepared by GCE A Level Mathematics. The universities had controlled Mathematics A
Level syllabi, and most students entering university were able to undertake their studies without encountering too much difficulty. Latterly this has not been the case and there is now a significant proportion of the student population who, as a result of their prior mathematical education, arrive poorly prepared to undertake university level mathematics and are in danger of failing to progress through their chosen course. To alleviate failure and drop-out rates and to assist an increasing number of students who are seeking help with the mathematical elements of their courses, many institutions have introduced some form of remedial engagement and additional mathematical support.

With the introduction of GCSE Mathematics came a reduction in content when compared to that included in General Certificate of Education at Ordinary Level (GCE O Level) (Sutherland & Pozzi, 1995:8). This has resulted in students, not only from mathematics, physics and engineering courses but also students from a wide range of disciplines such as psychology, business and social sciences, where GCE A Level Mathematics may not be a mandatory entry requirement, requiring mathematics support.

Since the arrival at university of the first candidates who had taken the GCSE examinations, there have been expressions of concern regarding the chasm between school mathematics and Higher Education (HE) mathematics. These concerns have been expressed in numerous journal articles, and inquiries have been undertaken to question the mathematical accomplishment of these students. In 1995 the London Mathematical Society (LMS), the Institute of Mathematics and its Applications (IMA) and the Royal Statistical Society (RSS) produced their report ‘Tackling the Mathematics Problem’, which investigated concerns amongst mathematicians, scientists and engineers in HE about the mathematical preparedness of new undergraduates. In 1995 the Engineering Council also commissioned a report to investigate anecdotal evidence and growing speculation that the mathematical background of undergraduate engineers had changed. The findings showed that, amongst this body of students, mathematical knowledge was weaker than it had been ten years previously (Sutherland & Pozzi, 1995). On a wider scale, the Gatsby Charitable Foundation sponsored a seminar to investigate the same issue but in departments of Mathematics, Physics and Engineering. Again, the findings showed strong evidence of a steady decline in basic mathematical
skills and increasing inhomogeneity in mathematical attainment and knowledge (Savage, Kitchen & Sutherland et. al., 2000).

There has, subsequently, been a number of government-funded inquiries, for example, `Inquiry Into A Level Standards' (Tomlinson, 2002), `SET for success' (Roberts, 2002) and `Making Mathematics Count' (Smith, 2004) investigating the standards, suitability and uptake of pre-19 mathematics qualifications. Following the Smith report, the Qualifications and Curriculum Agency (QCA) has undertaken a project to evaluate participation in GCE A Level Mathematics (QCA, 2006). These reports give credibility to the fact that there are real difficulties being experienced by both students and staff in numerate disciplines. Furthermore, `widening participation' and the variety of access routes to HE have resulted in students entering HE with a greater range of qualifications than was previously the case.

The HE sector has responded to these changes in several ways: many universities now use diagnostic testing to identify those students who are likely to experience difficulties with the mathematical elements of their courses. Those students identified as being at risk of failing are then often given follow-up support. Other routes that have been taken, by university departments, to cope with the teaching of mathematics to first year undergraduates include the redesigning of first year mathematics courses, the provision of remedial assistance, drop-in support and computer based mathematics learning centres (Savage, Kitchen & Sutherland et. al., 2000:3, LTSN MathsTEAM Project, 2002).

At Loughborough University, under the jurisdiction of the Mathematics Education Centre (MEC), we have a model Mathematics Learning Support Centre (MLSC), which is considered to be an exemplar for the UK and has influenced similar developments in many other institutions. The MEC has recently achieved Centre for Excellence in Teaching and Learning Status from the Higher Education Funding Council for England (HEFCE).

In February 2001, the MLSC initiated the provision of one-to-one support with mathematics for dyslexic students. This was introduced in response to a request from the English Language Study Unit (ELSU) at Loughborough University where a member
of staff responsible for giving one-to-one tutorial support to dyslexic students had encountered a student whose difficulties were of a mathematical nature. A member of the MLSC who is a competent mathematician and experienced teacher of mathematics provided this support. She subsequently gained knowledge and understanding in the field of dyslexia and also expertise in the teaching of mathematics to dyslexic students. The initial request from the ELSU was followed by several further referrals of students who were experiencing difficulties with the mathematical or statistical elements of their courses. In 2003, an increasing number of students requiring this form of support resulted in additional staff being recruited to the MLSC.

It had been established by the member of staff in the MLSC who supported the early referrals from the ELSU, that there was little, if any, useful information available regarding the ways in which these students might be assisted. This dearth of information inspired a joint effort between Loughborough, Coventry and De Montfort Universities, to form the Dyslexia and Dyscalculia Interest Group, now known as the Dyscalculia and Dyslexia Interest Group (DDIG), (www.ddig.lboro.ac.uk).

The Special Educational Needs Act (SENDA) (2001) amended the 1995 Disability Discrimination Act, making it applicable to all educational institutions and Local Education Authorities (LEA’s). It is now unlawful for a university to discriminate against a disabled student and this includes students with developmental dyslexia (for the research undertaken in this thesis it will be referred to simply as dyslexia). Moreover, universities are asked to make reasonable adjustments to ensure that disabled students are not placed at a substantial disadvantage when compared to non-disabled students. Concerning dyslexia and mathematics, it is not clear what constitutes reasonable adjustment and substantial disadvantage. Through the support that is offered to dyslexic students at Loughborough University and the findings from the dyslexia research described in this thesis, it has been determined where these students are disadvantaged and how they can be supported. These findings will enable mechanisms to be put in place to ensure that this legislation is complied with.
1.2 The Field of the Research

It is the aforementioned difficulty with mathematics, which has necessitated the implementation of mathematics support by many universities, and the apparent need for specialist help to assist dyslexic students that motivated the research that is described in this thesis.

The author of this thesis was of the opinion that research into the effectiveness of the mathematics support provided by Loughborough University, its suitability for dyslexic students and the difficulties experienced by dyslexic students with mathematics would provide a valuable contribution to those involved in the MLSC and the School of Mathematics. Moreover, it is also believed that the findings of this research may be generalised to other HE institutions and will, therefore, be of benefit to those involved in the design and provision of mathematics support, the provision of courses with a mathematical content, dyslexia support workers and also educational policy makers.

A literature search revealed that whilst there is a wealth of literature that discusses dyslexia, there is very little published work, or evidence of research, into the problems that may be encountered in the HE setting. The majority of literature relating to dyslexia is focused upon the needs of school children. However, from the available literature it is apparent, that, once a person has been diagnosed as dyslexic, the provision of specialist assistance may help with the development of compensatory strategies. Regarding the areas of dyslexia and mathematics in HE, there is even less published work or evidence of research. Additionally, it was determined that 'widening participation' and changes to mathematics syllabi were resulting in a growing need for mathematics support.

In certain disciplines, such as engineering, a shortfall in applicants has resulted in departments in some universities lowering their entry requirements. With a significant number of HE institutions in the UK offering mathematics support for students (Lawson, Halpin & Croft, 2001, 2002) and a significant increase in the number of students visiting the MLSC at Loughborough University, it was considered important to determine if the Centre was meeting the needs of the students who use it and why such support is necessary. Research into the effectiveness of the MLSC was also prompted by the possibility of an extension to and/or relocation of the MLSC.
As Loughborough University has a large Engineering faculty and Richardson and Wydell (2003) had established that the highest incidence of dyslexia in HE during the academic year 1995/1996 occurred in departments of engineering, it was decided to focus the majority of the dyslexia research in the field of the mathematical education of undergraduate engineers. Interestingly, Frey (1990:6) also believes that a significant proportion of engineers are dyslexic and that the current education system in the USA, which is more academic and less practical than was previously the case, is discouraging potentially innovative dyslexic students from entering engineering. All engineering courses contain compulsory mathematics modules and it has been determined by Pyle (2001) that many undergraduate engineers are in need of support with these modules. More specifically this thesis entitled ‘Mathematics Learning Support and Dyslexia in Higher Education’ investigates the effective learning environments and systems for supporting students in their study of mathematics, and the problems encountered by dyslexic undergraduate engineers with their mathematics modules. To date, it is believed that the literature does not report any in-depth research that has examined the difficulties encountered by dyslexic undergraduate engineers with the mathematical elements of their courses.

The research reported in this thesis has been conducted internally at Loughborough University and externally throughout the whole of the HE sector. The research undertaken at Loughborough University includes details of the mathematics support that was available to students prior to the introduction of the MLSC in October 1996. It was this earlier support that determined the need for the MLSC. Observational research has been undertaken in the MLSC to gain an understanding of the nature of the difficulties that are experienced by students using the Centre and to witness the level of support they receive from the staff who work in the Centre. Additionally, a census of all academic and academic-related staff in the School of Mathematics, many of whom are working or have worked in the MLSC, has been taken and similar questionnaires made available to students who frequently use the Centre. The focus of this strand of the research was to investigate the difficulties that are encountered with mathematics, the growing need for support with this subject, the motivation for working in and using the Centre, the effectiveness of the Centre, staff and student attitudes towards it, and to obtain suggestions for improvement.
The dyslexia strand of this research incorporates exploratory multiple-case studies, the provision of one-to-one mathematics support to dyslexic students and explanatory multiple-case studies. The exploratory studies were undertaken, with dyslexic students, to determine whether they were impeded in their study of mathematics as a direct result of their dyslexia. One-to-one mathematics support was provided to three dyslexic engineering undergraduates. This was undertaken to enable any difficulties that might be encountered by the students to be witnessed and subsequent support mechanisms to be explored, developed and implemented. The explanatory studies were undertaken, with an equal number of dyslexic and non-dyslexic engineering undergraduates, to investigate the particular mathematical difficulties that were experienced, and to determine if there were differences in the problems encountered and differences in approach to study and revision between the dyslexic and non-dyslexic students. One area identified by both the one-to-one support and the explanatory case studies was that results from Computer Assisted Assessment (CAA) had been instrumental to two students considering that they might be dyslexic. A small exploratory study was subsequently undertaken in an endeavour to establish if there was any indication to suggest that CAA impeded the performance of dyslexic students.

The external research involved a survey of 106 universities in the UK to determine the extent, and range, of mathematical support that was available (Perkin & Croft, 2004:14-18). This was followed by visits to five universities, who offered mathematics learning support, in order to determine areas of good practice and to investigate whether the support provided at Loughborough University could be improved upon and, if so, the ways in which this could be done. All the universities that had been identified as providing mathematical support were then contacted to determine whether or not they also provided dedicated one-to-one mathematics support to dyslexic students.

This mainly qualitative, and to a large extent practitioner-based, research has given rise to a thesis containing rich and descriptive narrative from dyslexic and non-dyslexic students, academic and academic-related staff. Areas of difficulty frequently experienced in mathematics by dyslexic engineering students are discussed and recommendations are made for measures to be implemented that will alleviate these difficulties. Also highlighted are the differences between dyslexic and non-dyslexic engineering students in their approach to studying and learning mathematics, and the
areas in which dyslexic students experience difficulty. The efficacy and operation of the MLSC is covered in detail and the suitability of the Centre for dyslexic students is also discussed.

This work also specifies areas that could be investigated more extensively and identifies other areas that could benefit from virgin research, all of which would add to the growing knowledge base concerning the problems that may be experienced by dyslexic students and the support that may be introduced to alleviate their problems.

Greater awareness of the difficulties that are encountered by students undertaking mathematics modules in HE combined with the provision of assistance at the level that is required, for both dyslexic and non-dyslexic students, has the potential to improve upon ‘student experience’ and ‘student satisfaction’, both of which are currently topical issues.

In summary, this thesis is concerned with investigating whether dyslexic engineers are impeded in their learning and understanding of mathematics as a direct result of their dyslexia and whether current practices of delivery and assessment disadvantage these students. It also investigates the extent of mathematics support in HE throughout the UK and the level of mathematical support that is provided for dyslexic students. An in-depth investigation of the MLSC at Loughborough University is undertaken to determine whether the level of support it provides is adequate for those who avail themselves of the service and also whether it is meeting the needs of dyslexic students.

1.3 The Research Questions

In order to successfully carry out this research into the effective learning environments and systems for the study of mathematics in HE, and the problems encountered by dyslexic undergraduate engineers with their mathematics modules, the following research questions were posed.
1. Does dyslexia impede the learning and understanding of mathematics in HE and, if so, in what areas are particular difficulties encountered and can these difficulties be mitigated?

2. Are dyslexic students disadvantaged in their learning and understanding of mathematics by practices in HE and, if so, what are these practices?

3. What is the extent, in UK HE, of the provision of mathematics support, and mathematics support for dyslexic students?

4. Is the Mathematics Learning Support Centre at Loughborough University providing the level of support that is required, and is it meeting the needs of both dyslexic and non-dyslexic students?

1.4 Training Undertaken by the Researcher

During the first year of this research the author attended several training sessions, seminars, workshops and a conference, all dedicated to dyslexia. This training was undertaken both internally at Loughborough University and externally in order to gain an understanding of dyslexia and an appreciation of the difficulties that may be encountered by the dyslexic population.

Other courses, not related to dyslexia, provided by Professional Development at Loughborough University have also been attended during the three years of this work. These courses have covered postgraduate teaching skills, tracing of journal articles, current school mathematics syllabi, plagiarism, citations, the role of the MLSC, interview techniques, questionnaire design, conference presentation skills, ethical issues, PowerPoint and issues relating to freedom of information.
1.5 Ethical Issues

The concise statement “Rigour, respect and responsibility: a universal ethical code for scientists” given by ‘The Council for Science and Technology’ (http://www.cst.gov.uk/cst/reports/) has provided the foundation for consideration of the ethical issues connected with this research.

Burns (2000:17-24) details many ethics of research and, of these, those that need consideration in this work are related to the voluntary involvement of people, and their institutions. It is necessary to obtain participants’ informed consent, consider the handling of personal and sensitive data, assure participants privacy and confidentiality, inform participants that they have the right to withdraw from the research, consider the time taken by the participants in relationship to any benefits that might ensue and to explain that publication of findings might ensue.

For the dyslexic and non-dyslexic students at Loughborough University who participated in the exploratory and explanatory case studies, and the dyslexic students who received one-to-one support, all were assured anonymity. Furthermore, the students participating in the exploratory and explanatory studies were informed that they could withdraw from the research at any time during the interview or subsequently provided their intention to do so was made known to the researcher prior to July 2006. None of the students who participated chose to withdraw from this research. All participating students have been given, or chosen, pseudonyms, which do not necessarily depict their true gender, however, to maintain accuracy the ratio of male/ female participants has been preserved. A consent form written in clear and unambiguous English outlining the nature and purpose of the research being undertaken and explaining that findings from the research would be included in the thesis written by the researcher and may also be published in academic journals or conference proceedings was signed by each participant. All data has been filed under the pseudonyms used. A list linking the students’ real names and their pseudonyms has been stored separately.

A small honorarium was given to students participating in the explanatory studies. This was a contribution for the time taken and any expenses that may have been incurred and was not of sufficient value to have induced any student to participate against his or her
better judgement. All participants seemed genuinely interested in the research being undertaken and were keen to speak of their personal difficulties and experiences. There were some students who did not want to accept the honorarium. Nevertheless, it was given to all those participating in the explanatory studies; three students stated that they would donate it to a charity. Gender issues have not been considered due to the predominance of male students registered on engineering courses, and at Loughborough University as a whole (details are given in Chapter III, section 3.7.2).

No ethical misconduct has knowingly been perpetrated. The data has been meticulously written up with no exaggerated claims being made in the subsequent conclusions. The author of this thesis did not commence this research with any pre-conceived ideas, related to the effects dyslexia may have on the learning and understanding of mathematics, which might have introduced bias into the reporting. The communication between the researcher and the students has been honest and accurate.

All institutions that were contacted for the survey undertaken to determine the extent and range of mathematical learning support in HE (Perkin & Croft, 2004:14-18) and in the subsequent survey to establish how widespread is mathematics support to dyslexic students in HE have been guaranteed anonymity. Some institutions that provide mathematical support may, however, be determined as a direct result of their advertising this facility on their university web site. The universities were categorised as Russell Group/ Red Brick/ Old/ New. The decision not to acknowledge the ancient status of those universities founded prior to the 19th century was made in order to ensure their anonymity. Five universities who offered mathematics learning support were visited and their learning support facilities viewed; staff at these institutions signed a consent form allowing their names and the name of their university to be cited. Academic and academic-related staff who completed the MLSC census forms, students who completed the MLSC questionnaires and students who participated in the CAA exploratory study have also been assured anonymity.

There is much discussion on the emotive issue of using 'labels' to classify people (Riddick, Farmer & Sterling, 1997:15-16), however, the decision has been taken to use the term 'dyslexia' in this work rather than, for example, 'learning disability'.
Furthermore, the expression ‘diagnosed as dyslexic’ has been used throughout this thesis rather than, for example, ‘found to be dyslexic’ or ‘identified as dyslexic’, and signifies that an Educational Psychologist (EP) has determined that a student is indeed dyslexic.

Additionally, to the author’s belief, all work of others has been accurately referenced.

1.6 Dissemination

Presentations, at both National and International Conferences have been given to disseminate the findings from this research. Additionally, workshops, focusing on the problems encountered by dyslexic undergraduates with mathematics, have been provided at National and International Conferences to promote discussion amongst attendees and also to generate ideas. Papers have been published (or are awaiting publication) in journals specialising in different areas in an endeavour to reach a wide readership. These different areas include mathematics, dyslexia, education, and computing.

1.7 Overview of the Thesis

The first undertaking was a review of the literature. Taking the approach that ‘widening participation’ is not just a modern phenomenon but, in a more general sense, is linked to educating inclusively our nation, an historical perspective of the educational system in the UK from the 18th century is given first. The literature review then commences with an appraisal of the changes to pre-university mathematics qualifications that have taken place during the last 20 years. It continues by looking at the problems that are now being encountered with mathematics by students entering HE and also the difficulties faced by universities as a result of these changes. The nature of dyslexia and the particular difficulties that may be encountered with mathematics are then covered. An outline of the historical perspective and the literature review, which form Chapter II of this thesis, are given next.
Since the 1870 Education Act introduced elementary education in England and Wales for children aged from five to 13, the school leaving age for compulsory education has been raised several times, educational qualifications are now taken by almost all 16 year olds and the current government objective is that 50% of young people aged between 18 and 30 years old will enter HE by 2010. The historical perspective covers the development of the educational system in the UK from the 18th century to the present time with emphasis on the reasons for, and difficulties encountered with, educating the nation.

The extensive literature search revealed a large number of reports, evidence of research and journal articles, which discussed mathematics qualifications, the mathematical knowledge of first year undergraduates and the mathematical difficulties students encountered at the school/ university transition. The review has sought to establish the impact that changes to the school mathematics curriculum and ‘widening participation’ have had on mathematics and mathematics-related disciplines in HE. Also reviewed and detailed in Appendix G are the measures that have been taken by universities, such as diagnostic testing and the introduction of mathematics learning support in response to the diversity of the student intake and the changes in, and range of, pre-university educational background of incoming students.

There is also a wealth of literature relating to dyslexia, which provides evidence of the growing awareness of, and research into it. However, research is predominantly undertaken with schoolchildren and publications relating to mathematics and dyslexia are primarily written to support teachers in their work with dyslexic children. Many of those undertaking research into dyslexia, for example, Riddick, Farmer and Sterling (1997:183), have written that there is little published research into dyslexia in HE. Since then attention has been drawn to dyslexia in HE by a report from the National Working Party on Dyslexia in Higher Education (Singleton, 1999), which focused on formulating guidelines for the identification and support of dyslexic students. However, the research undertaken with dyslexic adults has, in the main, been conducted from a psychological perspective, for example, the case studies undertaken by Edwards (1994) investigating the emotional impact of traditional education on eight boys aged between 16 and 17 and the studies investigating the personal experiences of 16 dyslexic students in HE (Riddick, Farmer & Sterling, 1997). Regarding the area of mathematics and dyslexia in
HE there is very little evidence of research; only a few journal articles discuss the subject in any depth. Moreover, in the specific field of dyslexic engineering undergraduates and the difficulties they may encounter with mathematics there is not any evidence of in-depth research in this area.

Chapter III contains two strands. The first is covered in sections 3.1-3.4 and commences with an historical overview of how dyslexia came to be recognised and the deficits that are associated with it. It continues by examining the three main theories relating to dyslexia that are currently undergoing extensive research. These are the phonological (retrieval of speech sounds) deficit, the magnocellular (auditory and visual) deficit and the cerebellar (motor control) deficit, which have all contributed to the emergence of dyslexia as an educational issue. The second strand is covered in sections 3.5 - 3.7 and commences by detailing the extent of dyslexia in the HE sector. It continues by describing the process at Loughborough University by which students are diagnosed as dyslexic, details the support that is available for dyslexic individuals within the university and the measures that have been taken to ensure that dyslexic students are not disadvantaged when compared to their non-dyslexic peers. It concludes with the results of an investigation undertaken to determine the number of students at Loughborough University who are diagnosed as dyslexic after commencing their undergraduate studies and the number who declare that they are dyslexic on application. Whilst the total number of dyslexic students in each department at Loughborough University is readily available, it was an extremely protracted task to determine how many students were diagnosed as dyslexic after entering university.

Chapter IV details the suitability of ‘Case Study’ as a research method for investigating the difficulties with mathematics that might be experienced by dyslexic students in HE, and the effectiveness of, need for, and attraction of the MLSC. An extensive review of literature on the use of case study was then undertaken and a resumé of this method is given in Appendix H. A description of how the exploratory, explanatory and one-to-one multiple-case studies, and the MLSC case study were designed in order to answer the research questions then follows.

Chapter V contains an account of the six exploratory case studies that were undertaken during the academic year 2003/2004 to determine if there was any evidence to suggest
that dyslexic students, who were studying courses with a significant mathematical content, were impeded in their learning and understanding of mathematics as a direct result of their dyslexia. Each study contains a triangulation of the data, which was obtained through interviewing the student, from reports given by one or more members of staff who knew the student and, where possible, from details given in the report written by the EP who diagnosed the student. Not only did these studies determine that there is evidence to suggest that these students experienced problems with mathematics that can be directly related to their dyslexia, they also enabled the researcher to gain experience in the use of case study.

Chapter VI provides a detailed look at particular areas of difficulty that were observed by the researcher during the provision of one-to-one mathematics support to three dyslexic engineering students. Patrick received support for two years and had been diagnosed as both dyslexic and dyspraxic (having motor control difficulties) early in the first year of his undergraduate studies. Russ received support for almost one year and Peter for one semester. In-depth case studies detailing the personal history of Patrick and Peter, the mathematical difficulties experienced by them, reports from members of staff who knew them and details from their EP reports are included. The difficulties encountered by Russ are also described. Weekly meetings with each student enabled the researcher not only to witness, at first hand, difficulties that were being encountered but also to gain an understanding and appreciation of the frustration that ensued. The support mechanisms that were introduced by the researcher to minimise these difficulties are also detailed.

Chapter VII contains an account of the 12 explanatory case studies that were undertaken during the academic years 2004/2005 and 2005/2006 to determine if, for dyslexic engineering undergraduates, there were any particular areas of mathematics that caused problems, whether there were any difficulties encountered with the delivery of mathematical material and if current assessment procedures might be considered to discriminate against them. Again, each of the case studies contains information obtained from interviewing the student, reports from one or more members of staff who knew the student and where possible the report from the EP who diagnosed the student. In addition to these case studies interviews were also undertaken with an equal number of non-dyslexic engineering undergraduates who acted as a control group. The non-
dyslexic students were posed many of the same questions as the dyslexic students thus enabling differences in approach to study, and areas of difficulty that were encountered, to be explored. One area identified by the explanatory case studies was related to the support that is provided for many dyslexic students, for example, the provision of notetakers, computers, what is deemed to be appropriate software, and coloured overlays. As approximately 60% of the Disabled Student Allowance (DSA) is used to provide support for students with dyslexia (Pumfrey, citing Laycock, 1998:88), the suitability of this support has also been questioned. Attention to this issue has also been raised by Price (2006:36) who emphasises that it is important to determine the individual needs of each student.

Chapter VIII details an exploratory study that was undertaken to investigate the use of CAA in mathematics and to explore the use of different media combinations. The aim of the study was to determine whether there is any evidence to suggest that this form of assessment discriminates against dyslexic engineering students and whether it gives a realistic indication of mathematical ability. However, the results proved inconclusive and in the final chapter it is recommended that a larger-scale study be undertaken. It was the low marks obtained in CAAs by a student who participated in the explanatory case studies and a student who received one-to-one mathematics support that motivated the author’s interest in this study, which was jointly undertaken with Dr. Beacham a Research Fellow at Loughborough University. A CAA test on the topic of integration was designed and presented in three different formats, text only, text and diagram, and text and audio. This test was undertaken by a total of 30 students (dyslexic and non-dyslexic). Considerable time was taken with the selection of the material to ensure that the test included questions similar to those that the author had observed causing problems to dyslexic students.

Chapter IX details the current extent of mathematic support throughout HE institutions in the UK. This research established that of the 106 universities contacted, 66 of the 101 responding institutions (65.3%) offered some form of learning support. There were an additional nine universities who would like to implement some form of mathematics learning support within their institutions but were prevented from doing so due to a lack of funding. This survey produced a response rate of 95.3%. Furthermore, to determine areas of good practice and to investigate whether the support provided by the MLSC
could be improved upon, five universities who offered mathematics support were visited. Details of the support provided by these universities, areas of good practice, and observations of unusual and original ideas that could be incorporated into the MLSC to enhance its image are given. An additional survey of those universities who offered some form of mathematics learning support was then undertaken to determine how widespread is the provision of one-to-one mathematics support to dyslexic students.

Chapter X covers the in-depth case study of the MLSC at Loughborough University. This study commences with an historical overview of the antecedents to the Centre. The information was obtained from interviews with current academic staff who were directly involved with obtaining funding for the provision of the MLSC, and a now retired former academic member of staff who offered some mathematical support prior to the introduction of the MLSC. The chapter continues by reporting the observed mathematical difficulties that occurred most frequently amongst students using the Centre and the observed attitude of lecturers on duty at the time. The greater part of this chapter is dedicated to the details obtained from, and analysis of, the census of the academic and academic-related staff in the School of Mathematics (many of whom work or have worked in the Centre) and the questionnaires completed by frequent users of the MLSC. Recommendations for improvements to the MLSC are also given.

The conclusion contains a discussion of the findings that have been obtained from this research and the implications of these findings. Recommendations are made for the implementation of measures, improvement to facilities and changes to practice within the School of Mathematics at Loughborough University. Some of the research allows generalization and suggestions are made for the implementation of measures by other institutions. If adopted, these measures would benefit not only individual institutions but also the students studying within them. It is recognised that there are resource constraints within many universities and also operational differences between establishments. Nevertheless, there is potential for uptake of some of the recommendations, particularly by universities who offer courses with a mathematical component. The thesis concludes with suggestions for larger-scale research in one area and makes suggestions for other avenues of research where findings may add to the knowledge base of dyslexia in HE and prove beneficial to dyslexic students.
II
Historical Perspective and Literature Review

There exist but a few issues, of national importance, in which the majority of the UK population have a serious interest. The care and welfare of the nation through its National Health Service is probably one and another is likely to be the education that an individual can expect to receive. Education has attracted discussion and controversy whenever decisions regarding its availability, content, delivery or funding have been made. Given this importance, to the individual and the nation as a whole, it is not surprising that the volume of literature in this field is vast.

The historical perspective and literature review commences with an introduction, which briefly relates the topics that will be covered. It then continues with a swift journey through the evolution of education in England (and occasionally Wales) followed by a brief summary of mathematics education at both GCSE and GCE A Level and the difficulties that have arisen since the implementation of GCSE. A more detailed investigation of the problems associated with students' level of prior mathematical knowledge, variations in mathematical knowledge within cohorts, and changes that have been introduced by those departments in HE with significant mathematics content are included in Appendix G. Finally, the issues connected with dyslexia and mathematics, both at school and in HE are reviewed.

2.1 Introduction – a general overview of the chapter

In the 18\textsuperscript{th} century the majority of the UK population had little or no education. There were some charity schools and other establishments where, for a few pennies a week, children up to ten years of age could receive a rudimentary education. However, education was not compulsory, and education beyond the age of ten was only available for those who could afford the fees. It was not until early in the 19\textsuperscript{th} century, as a result of rapid population expansion and the beginnings of the Industrial Revolution, that an educated workforce started to be seen as useful rather than threatening. Education of the
masses was to become regarded as a matter of urgency and in 1833 there commenced State intervention with the provision of funding for the building of schools. Whilst ‘widening participation’ is a phrase linked to the 21st century, it is also something that has evolved during a period of just over 130 years, since the 1870 Education Act (Forster Act) introduced elementary education in England and Wales for children aged from five to 13. Since then, through a succession of Parliamentary Education Acts, the provision of education has been extended to its present level.

Entry to HE is now perceived by the general public as available to all those that would aspire to it and benefit from it. However, prior to the widespread introduction of comprehensive education in the 1970’s, the possibility of attending university was still limited to a small percentage of the population. In the latter part of the 20th century there was a significant increase in the number of universities. This expansion was particularly noticeable in the 1960’s and in the 1990’s when colleges of technology and polytechnics, respectively, were granted university status. The current government policy is that 50% of the population, aged between 18 and 30, should enter HE by 2010. The HE participation rate for this age group during the academic year 2003/2004 was 42% and it is expected that the figure for 2004/2005 will be the same (http://www.dfes.gov.uk/rsgateway/DB/SFR/s000648/SFR14-2006.pdf). Section 2.2 gives an overview of education in the UK during the 19th and 20th century. A more detailed review, from the 18th century, is included in Appendix G.

It is inevitable that widening participation could not be put into practice without some difficulties; however, the difficulties encountered by students reading for degrees with a significant mathematical content are not a recent problem. The debate regarding the falling levels of the mathematical knowledge of incoming students and the declining number of students studying mathematics/ engineering has been raging for many years.

Since the mid 1990's there has been a plethora of reports relating to the difficulties and content of GCSE and GCE A Level Mathematics. The literature that has been reviewed includes numerous articles and reports relating to: the content of GCSE Mathematics syllabi, the decline in the number of students taking GCE A Level Mathematics and what has become known as 'the mathematics problem'. The severity of the problem has prompted successive governments to initiate inquiries into the situation and several changes to GCE A Level syllabi have ensued. Despite these inquiries and interventions, the reviewed literature shows that difficulties at the school/HE interface still exist.

For example, between 1989 and 2000 there was, overall, a reasonably steady growth in the number of students taking A Levels, from 661,591 in 1989 to 771,809 in 2000. However, during the same period, the percentage of candidates taking A Level Mathematics had been in almost steady decline, mathematics accounted for 12.8% of the total in 1989 and had fallen to 8.7% by 2000. As a result of Curriculum 2000, the overall number of A Level Mathematics candidates fell from 67,036 in 2000 to 53,940 in 2002. By 2003, the percentage of candidates taking A Level Mathematics had dropped to 7.5% (Porkess, 2003:13). These figures are shown in Table 1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total candidates</th>
<th>Mathematics candidates</th>
<th>Mathematics percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>661591</td>
<td>84744</td>
<td>12.8</td>
</tr>
<tr>
<td>1990</td>
<td>684117</td>
<td>79747</td>
<td>11.7</td>
</tr>
<tr>
<td>1991</td>
<td>699041</td>
<td>74972</td>
<td>10.7</td>
</tr>
<tr>
<td>1992</td>
<td>731024</td>
<td>72384</td>
<td>9.9</td>
</tr>
<tr>
<td>1993</td>
<td>734081</td>
<td>66340</td>
<td>9.0</td>
</tr>
<tr>
<td>1994</td>
<td>732974</td>
<td>64919</td>
<td>8.9</td>
</tr>
<tr>
<td>1995</td>
<td>725992</td>
<td>62188</td>
<td>8.6</td>
</tr>
<tr>
<td>1996</td>
<td>739163</td>
<td>67442</td>
<td>9.1</td>
</tr>
<tr>
<td>1997</td>
<td>777710</td>
<td>68880</td>
<td>8.9</td>
</tr>
<tr>
<td>1998</td>
<td>794262</td>
<td>70554</td>
<td>8.9</td>
</tr>
<tr>
<td>1999</td>
<td>783692</td>
<td>69945</td>
<td>8.9</td>
</tr>
<tr>
<td>2000</td>
<td>771809</td>
<td>67036</td>
<td>8.7</td>
</tr>
<tr>
<td>2001</td>
<td>748866</td>
<td>66247</td>
<td>8.8</td>
</tr>
<tr>
<td>2002</td>
<td>701380</td>
<td>53940</td>
<td>7.7</td>
</tr>
<tr>
<td>2003</td>
<td>750537</td>
<td>53917</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 1: Mathematics A Level Numbers and % of Entries.
(Taken from Porkess, 2003:13)
Section 2.3 reviews mathematics education since the introduction of GCSE. A detailed look at the content of, and the changes that have taken place in both GCSE and GCE A Level mathematics syllabi and the ensuing situation within the HE sector are included in Appendix G. That the increase in student numbers, which was due to an increase in the number of places in pre-1992 universities and also to an increase in the number of universities only became possible by making the entry qualifications easier to achieve has now become an annual media debate. Universities, it is also suggested, have lowered their entry requirements, to meet quotas, to fill places in less popular courses and to help bolster loss-making disciplines. Mathematics and subjects that have a significant mathematical content, such as engineering, are amongst those reported to be in general decline and in need of student recruitment to support their continued existence. With this suggested lowering of the academic threshold and a wider range of qualifications enabling entry to university, an increasing number of students are entering disciplines for which they are ill-prepared. Generally, universities offer students who are having difficulty with their studies some form of help and support. Regarding difficulties with mathematics, many universities now provide some form of mathematical support over and above timetabled lectures and tutorials. While this support, it is believed, is helpful for the majority of those who access it, for others it may be less effective. The problems that are encountered with mathematics at the HE interface, the impact that the changes to syllabi have had on HE and the measures that have been introduced by universities to alleviate the difficulties are also included in Appendix G.

Some students entering university are aware that they have a specific learning difficulty (SpLD) but others may be unaware that they have a recognised disability, such as dyslexia, which is causing them to have problems and may find that they are struggling to perform at an acceptable level in coursework and examinations. Not all of these students are diagnosed during their studies, but those that are can be offered help. Given the extent of this disability and the belief that many dyslexic students are gifted in a visually-creative way (Geschwind, 1982; West, 1997), it is not surprising that engineering departments contain a high number of dyslexic students; this has been confirmed by Richardson and Wydell (2003:490). It is dyslexic engineering students that are the focus of this research. Section 2.4 reviews literature appertaining to mathematics and dyslexia and the problems that may ensue in HE.
2.2 The Evolution of the Educational System in the UK

To give an insight into, and understanding of how, the current educational system has evolved, it is considered appropriate to place the subject of education and its development in an historical context. Appendix G takes us from the 18th century, when literacy was mainly a prerogative of the middle and upper classes of society, through State intervention in education, to the present where education is available for all. Whilst this historical consideration can only include the most significant aspects, it is believed that sufficient material has been included to give an overview of the changes that have taken place in our educational system. Figure 1 shows a timeline of some important developments in the provision of education since the 19th century.

Figure 1: Landmarks in the Evolution of Education

2.3 The Introduction of GCSE - Mathematics Education from 1986

In 1978 it was announced that the GCSE examination would be implemented and at that time there were concerns surrounding mathematics education and examinations. The Government established the Committee of Inquiry into the Teaching of Mathematics in Schools under the chairmanship of Dr. W.H. Cockcroft to investigate the teaching of mathematics at both primary and secondary school levels in England and Wales, with respect to the needs of pupils when they left school. The Cockcroft report entitled
'Mathematics Counts' was published in 1982. One recommendation was the need for a "differentiated curriculum" with a range of examination papers designed to meet the needs of the varying abilities of pupils aged 11-16 years. Another recommendation was for the implementation of a "foundation list" of mathematical topics to be identified by the committee (Cockcroft, 1982).

Since the first GCSE examinations in 1988 and the subsequent changes made to GCE A Level there have been numerous difficulties encountered with school mathematics education. Shortly afterwards problems also became evident throughout the HE sector in numerate disciplines. Concerns related to the level of mathematical accomplishment of these students have been expressed in numerous journal articles and reports. In addition to the inquiry into A Level standards, undertaken by Tomlinson (2002), there have been a number of government-initiated inquiries and high-level investigations carried out to investigate the state of mathematics education, which endorses the seriousness of the situation. The reports from these investigations also give credibility to the fact that there are real difficulties being experienced within schools and universities by pupils, teachers, students and lecturers.

In 2001, the government commissioned an investigation, under the chairmanship of Sir Gareth Roberts, into the supply of high quality scientists and engineers. The report entitled 'SET for success', detailing the supply of people with science technology, engineering and mathematics skills was published in 2002 and identified a number of issues in schools, Further Education (FE), HE and the workplace. Specifically referred to is the shortage of mathematics teachers, difficulties with the transition from GCSE to GCE A Level and that in relation to other subjects science and mathematics appear to be more difficult. Also referred to is the transition problem from GCE A Level to HE (Roberts, 2002).

In 2002, the government commissioned an investigation, under the chairmanship of Professor Adrian Smith, into the provision of post-14 mathematics education, in particular to investigate standards, suitability and uptake of pre-19 mathematics qualifications. The report entitled 'Making Mathematics Count' was published in 2004 and built on the earlier work of Sir Gareth Roberts. Smith identified areas of concern, most notably a shortage of specialist mathematics teachers and failure of the curriculum
to meet not only the needs of many learners but also the requirements and expectations of employers and universities. He also recommended that in England a high-level post be created in the Department for Education and Skills (DfES) with responsibility for mathematics (Smith, 2004). The government responded to this recommendation and in September 2004, Professor Celia Hoyles, Order of the British Empire (OBE) was appointed as Chief Advisor for Mathematics.

Most recently, the QCA has undertaken a project to evaluate participation in GCE A Level Mathematics and to investigate how take-up and retention might be increased (QCA, 2006).

With the examination system embracing a much larger percentage of pupils, there is, therefore, a much wider range of academic ability being examined. Both the GCSE and GCE A Level required subject content that could be taught and examined at this range of ability yet still differentiate between levels of achievement. It is inevitable that this increase in participation could not be implemented without some difficulties arising. GCSE Mathematics, GCE A Level Mathematics and the situation within numerate disciplines in HE are detailed in Appendix G.

### 2.4 Dyslexia and Mathematics

The word dyslexia is derived from two Greek words dys (meaning poor or inadequate) and lexis (meaning language or words) and is fundamentally a difficulty with language (http://www.healthatoz.com/healthatoz/Atoz/ency/dyslexia.jsp). There are two forms of dyslexia, namely, developmental dyslexia, which is recognised as a SpLD and acquired dyslexia, which arises from, for example, a stroke or head injury. Dyslexia can vary in severity and have a wide range of symptoms, which may differ noticeably between individuals (Singleton, 1999:25-29). Yet for many people the term dyslexia is only synonymous with poor spelling, indeed, Riddick, Farmer and Sterling (1997:175) in a text detailing case studies undertaken with dyslexic students in HE cite a comment from a non-dyslexic student:
You know there are so many dyslexic people doing engineering and I hate getting in a group with them because they can't write.

Difficulty with spelling is just one manifestation of dyslexia. Other difficulties may include problems with working or short-term memory, glare from print, and text appearing to move on the page (Singleton, 1999:27). The terms working memory and short-term memory are often used synonymously but in theory there is a difference. Working memory is a “theoretical framework that refers to structures and processes used for temporarily storing and manipulating information” whereas short-term memory is “the part of the memory that stores a limited amount of information for a limited amount of time (roughly 15-30 seconds)” (Wikipedia, http://en.wikipedia.org/wiki/). It is also known that there is co-morbidity between many developmental disorders, for example, dyslexia and attention deficit disorder (Frith, 2002:57). An historical overview of the developing concept of dyslexia is given in Chapter III.

In most areas, the ability to use and manipulate language is usually a prerequisite to learning, successfully, any topic that requires language as the vehicle with which to explain its content. The dyslexic student is, therefore, at a fundamental disadvantage when it comes to learning mathematics, and indeed subjects such as chemistry and physics. These subjects require not only language to explain the concepts with additional subject specific terminology being encountered, which is true of all subjects in HE, but they also require the learning of a symbolic language and Greek characters.

The case studies (see Chapters V, VI and VII), which have been undertaken during this research, involved dyslexic students with an average or above average mathematical ability relative to their age and intelligence. There are, however, some students who have a much lower mathematical ability than one would expect given their age and intelligence, such students are often described as suffering from dyscalculia. It is possible that some students may be dyslexic, some dyscalculic and others may be both dyslexic and dyscalculic. Malmer (2000:223-239) believes that dyscalculia should be used to describe students who have only mathematical difficulties. Trott (2005), from providing mathematics support to students with dyslexia and dyscalculia (at Loughborough University) has created a chart (see Figure 2) depicting the three possibilities (dyslexia, dyslexia and dyscalculia, and dyscalculia).
This chart first distinguishes between dyslexic students who are mathematically able and those who have mathematical difficulties. The particular difficulties that are encountered by those in each of the resulting categories are detailed and also the areas of study most frequently undertaken by students in each category at Loughborough University. The research in this thesis is focused on students who have entered HE to read for engineering degrees, which have a significant mathematical content. These students have obtained the mathematical qualifications required for entry and are not amongst those with the SpLD dyscalculia.
Amongst the mathematically competent students there are some who are unaware, before commencing HE, that they are dyslexic. These students have managed their difficulties in some way prior to their arrival at university. However, at this higher level of education such students often find that their previous, often unrecognised, coping strategies are no longer sufficient to deal with the demands placed upon them in HE and become aware that they are in need of assistance.

The number of students who have been diagnosed as dyslexic after commencing their undergraduate studies at Loughborough University during the academic years 2002/2003, 2003/2004 and 2004/2005 are given in Chapter III.

2.4.1 Dyslexia and Mathematics at School

During the last 20 years there has been growing awareness of dyslexia and a significant amount of research has been undertaken in this area. There are several publications that specifically discuss mathematics and dyslexia, for example, Miles and Miles (1992), Chinn and Ashcroft (1993) and Henderson and Miles (2001). These texts have, however, been specifically written to assist dyslexic pupils up to around 16 years of age. A special issue of the Journal of Learning Disabilities published in 2005 focused on ‘International Perspectives on Mathematics and Learning Disabilities’. The title is somewhat misleading as the collection of papers all discuss children with numeracy problems rather than mathematical problems. Whilst many children have difficulties with arithmetic, dyslexic children are likely to have difficulties, which are beyond those normally associated with this subject. The dyslexic pupil is likely to have problems that are not necessarily related to understanding the subject’s content but are linked to the process of an instructional method that requires a high level of literacy, attention to detail and good short-term memory. Miles and Miles (1992:xi) suggest that:

... the difficulties experienced by dyslexics in mathematics are manifestations of the same limitation which also affects their reading and spelling.
Henderson and Miles (2001:1) advise that particular difficulties experienced by dyslexic pupils can affect their ability to cope with mathematics at an early age and may also influence their decision to continue with mathematics. They also add:

Dyslexic pupils do not learn if they are just told about a mathematics topic orally; they have to be taught through multi-sensory methods if the teaching is to have any impact on their acquisition of mathematical skills.

What is not available amongst the literature is any evidence of research into dyslexic pupils who do not encounter serious difficulty with arithmetic, achieve high grades in GCSE Level Mathematics and only become strongly challenged by the material they encounter in GCE A Level Mathematics or university mathematics. Herein the term mathematics includes statistics, which poses particular difficulties to many dyslexic students (see Chapter VII). These difficulties are often due to the lengthy descriptive text that frequently accompanies the questions. Additionally, for those students who experience visual disturbance using statistical tables proves to be problematic.

2.4.1.1 Difficulties experienced with School Mathematics

There are many factors, which potentially contribute towards the difficulties that are encountered by dyslexic pupils with mathematics. These include directional confusion, sequencing problems, visual-perceptual difficulties, lack of spatial awareness, which is needed for place values, poor short-term and working memory, difficulties with accessing long-term memory and slow speed of comprehension (Chinn & Ashcroft, 1993:5-8). Henderson and Miles (2001:4-6) focus on three areas, which particularly affect dyslexic pupils' learning and understanding of mathematics; these are short-term memory weaknesses, language-learning weaknesses and organisational weaknesses, and these are detailed next.

(i) Short-term Memory Weakness

This weakness may affect the ability to accurately recall a sequential operation or multiplication tables. It may also cause affected pupils to lose track of where they are in
a particular sequence of mathematical steps and in which direction they should be working, i.e., left to right or right to left (Henderson & Miles, 2001:4). For example, when undertaking multiplication (containing more than single digit numbers) one works from right to left whilst in long division one works from left to right.

Of particular interest in the area of mathematics and memory is a controlled experiment conducted by Steeves (1983:141-152), which compared 54 dyslexic boys who were between ten and 14 years of age with a control group of 54 non-dyslexic pupils. The dyslexic boys were divided into two groups. One group had scored highly on the Standard Progressive Matrices test (SPM) and the other had an average SPM score. It is widely agreed that the SPM shows mathematical potential. The control group was also similarly divided. Whilst there was similarity between the results obtained in the SPM by both dyslexic and non-dyslexic pupils in the high groups when a test of school mathematics was administered, the high-scoring dyslexic group scored lower than the non-dyslexic control group and was on par with the average scoring control group. However, when the high scoring dyslexic group were tested on the Wechsler Memory Test their results were below those obtained by both of the non-dyslexic control groups. Steeves concluded that the high-scoring dyslexic group, despite their high potential, were handicapped in areas of mathematics that required the ability to memorise.

This is in accord with other studies that have been conducted, for example, that of Ackerman, Anhalt and Dykman et. al., (1986:222-232), where pupils with reading difficulties were most likely to be slow and inaccurate when answering mathematical questions. The evidence suggests an association between poor memory and weakness at mathematics. Lack of proficiency in recall of the ‘times tables’ seems to typify this difficulty. It is the lack of ‘automatization’, i.e. the difficulty to recall spontaneously that is strikingly evident in the dyslexic pupil (T.R. Miles, 1992:5-13).

In ‘paired associate learning’, which is, for example, the linking of a specific written letter and its sound, the dyslexic population have been found to perform less well than non-dyslexics (Miles & Miles, 1999:143). Furthermore, although the evidence is not conclusive, T.R. Miles (1992:2-3,18) considers that many dyslexic pupils will struggle with the recall and use of symbolic notation. An example of this is the weakness of dyslexic pupils’ ability to recall either auditorily or visually presented digits.
Both dyslexic and non-dyslexic pupils encompass a range of different learning styles, for example there are ‘Inchworms’ who become immersed in detail and ‘Grasshoppers’ who jump from question to question. However, independently of being dyslexic or non-dyslexic many pupils are neither inchworm nor grasshopper, more importantly they may be an inchworm for one particular topic and a grasshopper for another topic (Henderson, 1998:15-17). Whilst there is significant research into learning styles (Gardner, 1991; Burden, 2002:271-283; Mortimore, 2003; Reid, 2005) it is not considered in the research being undertaken herein. This research focuses on the difficulties with mathematics encountered by dyslexic undergraduate engineers and the ways in which they might be assisted. It is, in the main, not dependent upon individual learning styles.

Mathematics is a linear subject that builds upon previous knowledge and understanding. In the teaching of mathematics to dyslexic pupils, T. R. Miles (1992:86-91) stresses that a great deal of time needs to be spent on the repetition and reiteration of key points and the devising of strategies that will enable these pupils to formulate a sequence and to systemise a process without necessarily having to recall all the stages from memory.

(ii) Language-learning Weakness

The language based learning difficulties experienced by dyslexic pupils also causes problems with the learning of mathematics. It is difficult for dyslexic pupils to learn the meaning of the symbolic language, for example, the different style of brackets that are used in different areas of mathematics. Place values are more important in mathematics than in writing; a spelling mistake will not generally render a word to be incomprehensible whereas a reversal of numbers is not easily detectable and will produce an incorrect answer. Algebraic notation requires flexibility, a sense of direction and the understanding that a term such as $3x$ represents a number. Fractional representation also poses particular difficulty, as the manipulation of fractions is not the same as that of whole numbers. All of these difficulties are in addition to dealing with and understanding the text of a mathematics question. The language used in a mathematical context can often be confusing to the dyslexic pupil as many words that are encountered have a different meaning to those that are seen in everyday life. For example, the student faced with understanding the difference between division as a
mathematical operation and the premier division in football may find themselves at a momentary loss (E. Miles, 1992:58-69).

To instruct dyslexic pupils verbally, on how to solve mathematical tasks, is to court failure as we are expecting them to be proficient in an area in which they are known to be cognitively weak. Extensive research all points to the dyslexic population as having difficulties with phonological processing (the meaning of and production of speech sounds). Nevertheless, with the introduction of a game, which is used to practice subtraction skills, whereby the manipulation of physical objects represents the numbers involved in the subtraction process it became evident that the use of objects, their physical manipulation and the use of language to describe the process helped a particular pupil with the mastery of a technique which had previously not been succeeded in. The multi-sensory use of verbal labelling coupled with moveable objects helped to reinforce an understanding of what was actually taking place in the subtraction process (Kibel, 1992:41-45).

(iii) Organisational Weakness

The inability of dyslexic pupils to grasp the concept of timetables and to set out their work clearly and systematically are both examples of organisational weaknesses (Henderson & Miles, 2001:5).

Motor-skills deficits such as clumsiness, have, traditionally, been regarded as common in dyslexic children. Such children often have a history of difficulty with co-ordination such as that involved with learning to ride a bicycle or learning to tie shoelaces. Moreover, deficits in fine motor skills often make it difficult for the dyslexic pupil to write clearly (Beaton, 2004:128).

Related to the three aforementioned areas of weakness there is an extensive list of difficulties that may be encountered by the dyslexic pupil when learning mathematics. For example, correctly ordering the days in a week, memorising times tables, accurately reading numbers, simple computation, remembering mathematical symbols and the context in which they are used, alignment of work and order of working. Given that the dyslexic pupil does not learn from a solely verbal delivery of a topic, it is necessary to
devise strategies that address the particular difficulties that dyslexics have. In simple
terms the mathematical needs of the dyslexic pupil are distinctive and need addressing
by the use of particular techniques (Henderson & Miles, 2001:1-6).

In summary, T. Miles (1992:17-18) finds that for school children:

- All or most dyslexics have mathematical difficulties of some kind, but these can
  be overcome to varying degrees and in some cases dyslexics can become extremely successful mathematicians.

- They are likely to have problems in their immediate memory for 'number facts'
  and where it is necessary they may resort to compensatory strategies such as
  counting on their fingers or putting marks on paper.

- They have difficulty in learning their tables and, in reciting them, may lose the
  place or become confused.

- They may also lose the place in adding up columns of numbers.

- Their difficulties over 'left' and 'right' may affect their calculations.

- They are helped if the basic concepts (addition, and so on) are introduced with
  concrete examples (adding and taking away blocks, for instance); otherwise the
  notation is far harder to understand.

In addition to these problems, there are, of course, the phonological deficiencies, which
can make the comprehension of mathematical texts extremely difficult. Nevertheless,
there are dyslexic pupils who struggle with early number work yet succeed in more
advanced mathematics (Chinn & Ashcroft, 1993:8).

2.4.2 Dyslexia and Mathematics in Higher Education

Over recent years the number of dyslexic students entering university and the number of
students being diagnosed as dyslexic after entry to HE has been steadily growing in the
UK (data confirming this is presented in Chapter III). With this increase in numbers has come a greater awareness of the problems that might be encountered within HE and in 1999 the report ‘Dyslexia in Higher Education: policy, provision and practice’ funded by the Higher Education Funding Councils of England and Scotland was published. The intention of this work, which contained data on the representation and attainment of dyslexic students, was to focus attention on improving policies, and provision of support in HE (Singleton, 1999), but Hatcher, Snowling and Griffiths (2002:120) in their discussion of the report comment:

Arguably, however, many of its recommendations were grounded in clinical experience rather than in systematic research. It is important to increase the evidence base on which recommendations can be made both about the support dyslexic students need and the allowances they may require.

This is in agreement with Riddick, Farmer and Sterling (1997:184-185) who recommend that research should be undertaken to determine the needs of dyslexic students, to evaluate the effectiveness of support mechanism, to evaluate the coping strategies of individual students, and to evaluate and develop computer software.

The research that has been undertaken for this thesis has been conducted mainly from a practitioner perspective and will provide a solid foundation for determining the mathematical support and allowances that are needed by dyslexic engineering students in HE. Moreover, through the provision of one-to-one mathematics support and the explanatory multiple-case studies (see Chapters VI & VII) the difficulties that are encountered and the effectiveness of support mechanisms have been investigated. Coping strategies are also suggested and their effectiveness observed.

2.4.2.1 Difficulties experienced with HE Mathematics

From the problems that have been detailed earlier regarding short-term memory, working memory and language-based difficulties, it might well be concluded that any problems that have been encountered by dyslexic pupils will be greatly magnified upon entry to HE. At this level of study greater demands are placed upon a student in terms
of: note-taking, additional symbolic notation that is encountered and lengthy multi-stage mathematical operations, which make demands upon short-term and working memory. Yet the amount of published research concerning dyslexia in the HE sector is small. Furthermore, much of the research that has been undertaken with dyslexic adults in HE has been approached from a psychological perspective, such as that undertaken by Riddick, Farmer and Sterling (1997) whose subjects had failed in mainstream education and overcame tremendous emotional and academic hurdles to obtain places in HE.

Many of those who are active in the field of research into dyslexia advocate that more research at the HE level should be undertaken. For example, Riddick, Farmer and Sterling (1997:183) write:

There is as yet, little systematic published research into dyslexia in higher education although in the last 3 years some institutions funded by the Higher Education Funding Council, have been investigating the needs of this group.

Since the publication by Singleton in 1999 there has been greater awareness of dyslexia in the HE setting and subsequently there has been an increase in the number of texts that focus on the needs of dyslexic students. For example, Hunter-Carsch and Herrington (2001) discuss effective learning for dyslexic students at the secondary and tertiary levels. Heaton and Mitchell (2001) offer advice to students who are dyslexic or think that they might be. Farmer, Riddick and Sterling (2002) from undertaking research into assessment of and support for dyslexic students in HE have published a book of their findings. Pollak (2005) interviewed 32 dyslexic students from four UK universities to determine individual experiences and self-concepts.

JISC TechDis, whose primary focus is “to support practitioners and managers in carrying out their organizational roles, promoting the use of technology to encourage inclusivity and address disability in education”, have also been active. They held their first conference in October 2005, which included a workshop on Dyslexia and Assistive Technology (JISC TechDis, 2006). Prior to this they published a booklet investigating the needs of disabled learners in technology and learning (JISC TechDis, 2002).

There is also growing awareness of SpLDs (which includes dyslexia) amongst academic and academic-related staff in HE. The University of Plymouth has undertaken a three-
year case study, funded by the HEA, to develop and promote inclusive approaches to assessment. Students reading for a degree in Architecture and Environmental Building were offered a choice of three assessment methods for one of their modules. The options were an end of module test, coursework or submission of a portfolio of work. The marks obtained by the students, when undertaking their chosen assessment method, showed an improvement in performance compared to previous years (The SPACE Project, http://www.space.ac.uk). The LTSN Engineering commissioned the publication of a resource guide to detail good practice, which, if adopted, should ensure accessibility for students with disabilities. This guide is primarily written for those working with engineering students with disabilities (LTSN Engineering, 2002). Furthermore, the provision of funding through the HEFCE Strand 2 initiative for ‘Improving Provision for Disabled Students’ should enable greater understanding of disabled students’ needs to be disseminated across the HE sector. A two-year project that has been awarded such funding is research into Accessibility in Learning Environments and Related Technologies (ALERT) jointly undertaken by the Universities of Durham and Bournemouth. This case study research is not technically focused but investigates “the role that Virtual Learning Environment (VLE) plays in supporting the attainment of pedagogical objectives by disabled students”, and includes a dyslexic student who is studying mathematics (Boyd, Pavey & Newland, 2005:11-13).

Most research that is undertaken with dyslexia and numeracy or arithmetic (often misleadingly labelled as mathematics) has a propensity of being published in journals in the fields of dyslexia, psychology or education and is therefore unlikely to be read by many mathematicians in the HE sector. To raise awareness of the difficulties encountered with mathematics by dyslexic students, not only is research in this field needed but the findings also need to be published in mathematics and engineering educational journals. One move in this direction was undertaken by Chinn, Elswijk, and Harmsen et. al., (1999:118-122) who published a paper in ‘Mathematics Today’ containing three dyslexic research studies. Whilst this publication will have reached many mathematicians the problems that are discussed in the paper all relate to those experienced by dyslexic schoolchildren.

It may reasonably be assumed that many dyslexic students encounter problems at the outset of their education and dyslexia will have been recognised and diagnosed. This is not always the case as many of the students who participated in the research detailed in
this thesis were able to manage any difficulties that they encountered with the more elementary aspects of their education and it was only after commencement of their undergraduate studies that dyslexia became suspected and later diagnosed.

The dyslexic student arriving at an HE institution to read for a degree with a significant element of mathematics will have, by necessity, reached a reasonable standard in this subject. Students at this time may or may not be aware that they are dyslexic, but may have been taught coping strategies or developed coping strategies, which have enabled them to reach the required level of competence. The idea that students master their dyslexic difficulties and they no longer form an obstacle to progression is incorrect; the underlying problems still remain. Nevertheless, there are, amongst the dyslexic population, those who have struggled with basic arithmetic and become professional mathematicians or physicists (Perkin, Croft & Grove, 2006:20-22).

These difficulties with arithmetic are evident in dyslexic students who had entered HE and intended to progress to teaching. Morgan and Rooney (1997:29) found that, apart from language difficulties, dyslexic students still had fundamental difficulties with their multiplication tables. Amongst studies, which investigate the dyslexic adult, some have used HE students as their subjects, and consequently are of particular interest here.

In a HE setting, Ramus and his colleagues examined 16 dyslexic and 16 control students from University College London to assess the three leading theories of dyslexia and their prevalence in this particular setting. These theories are phonological (retrieval of speech sounds), magnocellular (auditory and visual), and cerebellar (motor control), which are discussed in Chapter III. A battery of tests was administered to the subjects and the most significant deficit (apparent in all the dyslexic students) was found to be in phonological skills, which is in accord with other studies that have been undertaken. Additionally, out of the 16 dyslexic students, ten had disparate auditory problems that could not be consistently related to any particular deficit theory of dyslexia, four were found to have motor deficits and only two had visual problems. What is evident from these results is that there appears, at least in this sample of students, to be a scattering of symptoms amongst them (Ramus, Rosen & Dakin et. al., 2003:841-865).

Although the previous study was not of a mathematical nature the results demonstrate that those providing assistance to dyslexic students in HE, whatever their discipline,
need to recognise this diversity of symptoms, need to have a flexible approach and offer appropriate support methods.

Research undertaken by Hatcher, Snowling and Griffiths (2002:119-133) investigated the performance of 23 dyslexic and 50 control students at the University of York. These students came from a range of different departments, which included some students from Mathematical Sciences (records at York University showed that 18% of their dyslexic students were located within this department). A series of tests were administered including a self-perception test. It was found that there were significant cognitive differences between the control group and the dyslexic group. Deficits in phonological analysis, decoding and processing were strongly evident along with short-term memory problems and slow speed of processing. Looking at these deficits, the researchers found that:

Together these difficulties resulted in poor arithmetic performance, except for students studying mathematical sciences who performed at the control level on the mental arithmetic test.

A one-day conference held at Hull University in 2003, brought together those with an interest in supporting the growing number of dyslexic students in HE and FE. In the proceedings of this conference (which was edited by Pollak) Trott and Wright (2003:76-91) discuss the problems experienced by dyslexic and dyscalculic students studying mathematics in HE and FE, and emphasise that this is a largely un-researched area.

Peer (2003:5-19) notes that there are clearly fewer dyslexics in HE than in schools but in her assessment of their educational needs she presents many ‘study skill’ issues that are pertinent to dyslexic students irrespective of their level of education. She also adds that one-to-one specialist support should be available if required. Dyslexic students need additional support with their studies; for example, in the way material is taught, the way it is presented and the way it is examined, if they are to be successful.

Trott, a founding member of the DDIG and a mathematics tutor supporting dyslexic students with mathematics and statistics in HE, gives examples of problems that she has witnessed. These include students losing their way in multi-step operations, difficulties with recalling and manipulating formulae, and sequencing problems. Also, not surprisingly, they have difficulty in extracting what is actually required when faced with
predominantly text-based questions and may also have difficulty relating a word to both its procedure and its symbolic notation. A crucial point put forward by Wright is that “good teaching for dyslexic students is often just ‘good practice’ for teaching anyone”. She explains that in mathematics, which is a linear and cumulative subject, organisation is important. Therefore, the taking of notes and the orderly structuring of files is essential to enable continuity of learning and to provide a source from which the subject can be revised. As disorganisation is a characteristic trait of dyslexia this requirement for organisation places an extra burden on the dyslexic student. She suggests that this can be overcome, in a FE setting, by the sharing of good practice amongst peers (Trott & Wright, 2003:76-91).

In a study undertaken with dyslexic and non-dyslexic students to investigate dyslexia and everyday memory, Smith-Spark, Fawcett and Nicolson et. al., (2004:174-182) found that dyslexic students had a higher frequency of everyday lapses in cognition than their non-dyslexic peers. In addition to the organisational problems that were experienced by the dyslexic students, difficulties were also evident in their everyday life. Hatcher, Snowling and Griffiths (2002:119-133) found that dyslexic students in HE have difficulty with academic and academic-related skills, which compensatory strategies are unable to overcome. In their discussion of the research they stress that:

The areas of greatest concern for dyslexic students, as adduced from interviews with them, were rate of reading, writing, memory and time organisation. Moreover problems of memory and attention were the most widely noted symptoms on the protocols they completed (ADD [Attention Deficit Disorder] Scales). ... The area of greatest concern, however, both by the dyslexics and their departments was in constructing writing.

A dyslexic engineering student, who was supported with his mathematics modules in HE, is described by Trott (2002:26-27) as having difficulty with his handwriting speed and general note taking and also exhibiting a disorganised approach to his work. He was helped to overcome his difficulties by the use of visual images, tree diagrams, spider diagrams and coloured paper. It was also apparent that he needed a lot of time to assimilate information, and care needed to be taken not to overload him with too much new material in any one session.
Searle and Sivalingam (2004:3-5) have undertaken some preliminary work in the field of dyslexia and mathematics in HE and conclude:

The possibility of a dyslexic pupil experiencing serious difficulties with tertiary mathematics despite having excelled in school mathematics is real.

More recently Simmons and Singleton (2006:96-114) have undertaken a study with 19 dyslexic and 19 non-dyslexic students, the aim of the research being “to determine whether dyslexic individuals’ difficulties with number recall continued into adulthood”. They found that the dyslexic students were less accurate than the non-dyslexic students when undertaking subtraction and multiplication operations. When correctly answering addition and subtraction questions they performed more slowly than the non-dyslexic students. The authors do, however, point out that it is not known what courses the students were undertaking and there may have been a preponderance of dyslexic students from the arts rather than the sciences.

There are also broader issues that may impact on students in HE regardless of their chosen discipline. From a small study of six universities, Sanderson and Pillai (2001), found significant disparity between them in relation to the range of provisions available for dyslexic students. From the data collected they judged that there may well be ill-judged recommendations for appropriate software. There was also great variation in examination procedures, marking and allocation of extra time. Furthermore, none of the universities had an adequate number of support staff to give one-to-one support when this had been awarded. They describe the situation as “The Lottery of Learning Support in Higher Education”.

Whilst a significant proportion of both dyslexic and non-dyslexic engineering students are in need of extensive support to meet the rigours of the mathematical content of their courses, it is often the dyslexic students who pose the greatest difficulty to academic and support staff, as it is certainly not clear what is the best strategy for helping each individual.

Compared to the wealth of literature relating to problems and difficulties associated with mathematics in HE, that concerning dyslexia and mathematics, at this level, is sparse. Magne has compiled a bibliography entitled ‘Literature on Special Educational Needs in Mathematics’ (http://www.bit.mah.se/MUEP), which contains references to
about 5,000 documents. This exceptional undertaking, which covers areas such as anxiety and cerebral palsy does not have a specific section entitled dyslexia and includes references to many papers, which are not published in English. This unfortunately makes it difficult to use. In order to establish what support is required to assist dyslexic students with the mathematical content of their undergraduate courses and to ensure that these students are not disadvantaged compared to non-dyslexic students it is imperative that more research in this area is undertaken.
It is reasonable to assume that dyslexia like many human conditions has always been present in the general population. Unnamed and unrecognised it would, however, have remained undetected prior to the advent of speech and, more crucially, the invention of writing. It would only become noticeable with the introduction of a more widespread, if somewhat elementary, educational system. If dyslexia has a history, it is of its discovery as a condition and the many attempts to describe, understand and satisfactorily explain its origin, cause and remediation. Even with current advances in technology, the causes of dyslexia have yet to be agreed upon, nor yet has there been found a single definition upon which interested parties can agree. There are many definitions of dyslexia ranging from those couched in scientific terminology to brief statements referring to difficulties with reading and spelling. The British Dyslexia Association (BDA) in the Dyslexia Handbook (2002:67), give the following definition:

Dyslexia is best described as a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling and writing. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, sequencing and organisation, auditory and/or visual perception, spoken language and motor skills. It is particularly related to mastering and using written language, which may include alphabetic, numeric and musical notation. Some children have outstanding creative skills, others have strong oral skills. Some have no outstanding talents. All have strengths. Dyslexia can occur despite normal intellectual ability and teaching. It is independent of socio-economic or language background.

Whilst many people perceive dyslexia as an inability to spell combined with confusion relating to some letters and numbers, dyslexia manifests itself in many other ways, some of which, or all of which, may be experienced by the dyslexic population. When problems are encountered with one or more of: visual disturbance, short-term memory or working memory, these pose particular difficulty in the study of mathematics. There is no 'cure' for dyslexia. Nevertheless, once an individual has been diagnosed as
dyslexic there is support and assistance that can be given to help with the development of compensatory strategies. Indeed, as mentioned earlier it is vital that suitable support is given and adjustments made in order to comply with SENDA.

As a result of the widening participation programme in the UK, it was expected that HE institutions would see a significant increase in the number of dyslexic students registered on their courses. This expectation is indeed a reality and statistics from the Higher Education Statistics Agency (HESA) detailing this growth are given (see section 3.5). Prior to conducting research into dyslexia and its effects on the learning and understanding of mathematics it was considered important to determine not only the number of engineering students at Loughborough University who registered on entry that they were dyslexic but also the number who were diagnosed as dyslexic after the commencement of their undergraduate studies.

This chapter contains two distinct parts. Part one (sections 3.1 - 3.4) covers an historical overview of the developing concept of dyslexia. Part two (sections 3.5 - 3.7) covers the number of dyslexic students in HE, the number of dyslexic students at Loughborough University and the support that is provided by Loughborough University for dyslexic students.

3.1 Historical Overview of the Developing Concept of Dyslexia

From the 19th century onwards, with the spread of literacy and education, more and more individuals became aware that they had noticeable language difficulties. Initially, medical practitioners began to recognise that amongst those patients who had suffered damage to a specific area of the brain, there were some who subsequently developed difficulties associated with language and reading. Confusingly though, there were also some individuals who had not suffered brain damage but showed similar symptoms. At this time medical practitioners were also aware that some adults had greater difficulty than others with basic language skills or no ability at all to understand or produce speech and, in some of these cases, the difficulties appeared to be the result of an injury to the brain. These conditions, ranging from complete inability to understand or produce
speech through to various combinations of speech and reading difficulties were called the aphasias (Miles & Miles, 1999:1).

Although not the first medical practitioner to carry out post mortems on the brains of patients who suffered from speech disorders, Pierre Broca, a French physician, anatomist and anthropologist, in 1861, found that “local disease of one half of the brain produced definite loss of speech”. Broca located the cause of the disorder in the third frontal convolution (located in the frontal lobe, as shown in Figure 3), which gave credence to the theory of ‘localisation’ (Head, 1920:88). The area identified by Broca became linked to his name and hence has become known as ‘Broca’s area’ (Miles & Miles, 1999:2), this is shown in Figure 4. The basic concept that speech functions could be located in a restricted area of the brain was established, although this would turn out, in the longer term, to be an oversimplification.

Figure 3: Areas of the Brain 1
(obtained from Google Images)
In 1878 the German physician Kussmaul introduced the concepts of 'word deafness' and 'word blindness' to explain the inability of some patients to use language correctly. The translation of his writing is that:

Patients who suffer from word deafness and possess at the same time the ability to express themselves in words, but use many words in the wrong places, and often distort them, leave on the minds of the observers the impression that they are crazed.

(Miles & Miles, 1999:3).

Kussmaul also pointed out that these patients are not really deaf as they can recognise sound but complete text-blindness can exist "even though the power of sight, the intellect and the power of speech are intact" (Miles & Miles 1999:3). What Kussmaul had recognised was that this condition could be present in patients who had not suffered an accident or been subject to a disease affecting their brain.
The term dyslexia was first used by the German ophthalmologist Berlin in 1887 when he described reading difficulties caused by cerebral (pertaining to the front of the brain) disease or injury, as opposed to difficulties in patients who had not suffered brain damage (Beaton, 2004:3-4). In 1891 the French neurologist Dejerine suggested that damage to the left inferior parieto-occipital (the left angular gyrus) region could, in adults, result in severe impairment in reading and writing (see Wernicke’s area in Figure 4) and in 1895 Hinshelwood, a Glasgow eye surgeon, published work agreeing with this theory (Habib, 2000:2374). Hinshelwood, in a number of papers published at the end of the 19th century, described cases of acquired word and letter ‘blindness’ where patients did not exhibit conspicuous speech difficulties (Beaton, 2004:3-4). Not surprisingly then, in the latter part of the 19th century, people began to think that dyslexia might have a neurological (related to the nervous system) origin. Additionally, there was some recognition of the similarity of symptoms exhibited by those patients with aphasia and those patients who had no history of brain damage.

The early work and reports of Hinshelwood encouraged Dr Morgan, a general medical practitioner, to write to The British Medical Journal in 1896 and describe the condition he named as “congenital word blindness” (congenital being a condition that is present from birth rather than acquired) in relationship to a boy Percy F. His account is:

Percy F. — a well-grown lad, aged 14 — is the eldest son of intelligent parents ... He has always been a bright and intelligent boy, quick at games, and in no way inferior to others of his age. His great difficulty has been - and is now - his inability to learn to read. This inability is so remarkable, and so pronounced, that I have no doubt it is due to some congenital defect ... the greatest efforts have been made to teach him to read, but, in spite of this laborious and persistent training, he can only with difficulty spell out words of one syllable ... The schoolmaster who has taught him for some years says that he would be the smartest lad in the school if the instruction were entirely oral ... His father informs me that the greatest difficulty was found in teaching the boy his letters, and they thought he never would learn them. (Morgan, 1896:1378).

This was the first description of congenital word blindness in medical literature; the condition is now described as developmental dyslexia. Hinshelwood, in the early 20th century, after seeing two boys and subsequently a further four cases from the same
family reported that they also had the condition of ‘congenital word-blindness’ (Beaton, 2004:4). Additionally, Hinshelwood and Morgan considered that there may exist some cases of defective development in the region of the brain identified by Dejerine and that the condition might also be hereditary (Habib, 2000:2374).

Between 1900 and 1917 Hinshelwood wrote extensively on the subject of word and letter blindness, and congenital word blindness. He believed that a greater understanding of the developmental language disorders in children would benefit from the study of acquired language disorders in those adults who had sustained brain injury. He also believed that the problems were physiological (science of the process of life), probably ran in families, were more prevalent in boys but could be helped by appropriate teaching methods (Miles & Miles, 1999:4-7).

The views of Orton, an American neurologist who was notable in the field of dyslexic research, were also similar to those held by Hinshelwood. Orton was involved in a large survey in which, during 1925, over a 1000 cases in Iowa were investigated. However, unlike Hinshelwood he felt that terms like ‘word blindness’ used in relationship to dyslexia were misleading, as there was not any true blindness involved; he preferred the concept of a developmental condition and coined the term ‘strephosymbolia’ (the twisting of symbols). Amongst the observations of Orton were the frequent reversals of letters in written work where b was confused with d and p was confused with q, also the misinterpretation of words such as was being interpreted as saw (Miles & Miles, 1999:7-8). At this time all three of the researchers, Morgan, Hinshelwood and Orton, who were involved in the field of developmental dyslexia, thought that it was perceptual and caused by visual confusion (Stein, Talcott & Walsh, 2000:209).

Whilst the work of these early pioneers can be readily criticised given later research, they did lay the foundations for future study and their work was to be followed by an ever-growing number of researchers who identified the many forms that developmental dyslexia could take. Like subjects within many disciplines, dyslexia is undergoing intensive scrutiny; there are many competing theories relating to the cause(s) and the best methods of remediation.
Given that, at least currently, there does not seem to be a single identifiable cause of dyslexia there is acknowledgement that an interdisciplinary approach encompassing the three main theories of dyslexia might provide a more satisfactory explanation (Reid & Fawcett, 2004:4). These three theories are discussed in section 3.3.

What seems to be agreed upon is that there is a difference between the structure and functioning of the dyslexic brain when compared to the non-dyslexic brain. It is also clear that there is not necessarily a single difference in structure and function of the dyslexic brain or that the causes of these differences can be absolutely, as yet, identified. However, it is apparent that related to these differences there are language and other difficulties, which manifest themselves in the dyslexic student (Murphy, 2003:340-342). It is generally thought that dyslexia can be familial and that it is more prevalent in males, although this is not universally agreed (Habib, 2000:2374).

Beaton (2004:10) explains that the prevalence of dyslexia varies from country to country, being dependent on the language spoken; incidences may be less in countries where there is more consistency between sounds and letters than in English. He also cites Makita who found that less than 1% of Japanese school children had a reading disability.

There has been a move away from using the expression ‘diagnosed as dyslexic’ due to its medical connotations and the fact that dyslexia is determined by an EP not a medical practitioner. Indeed, the ICD-10 Classification of Mental and Behavioural Disorders (World Health Organization, 1993:142-147), whilst referring to unspecified specific developmental disorders of scholastic skills, no longer specifically refers to dyslexia. The description given is that this category should be “avoided as far as possible and should be used only for unspecified disorders in which there is a significant disability of learning that cannot be solely accounted for by mental retardation, visual acuity problems, or inadequate schooling”. Critchley (1970:24) points out that dyslexia is not confined to a particular level of intelligence, although he recognises that it might be more difficult to diagnose in those children in the lower Intelligence Quotient (IQ) range. However, Beaton (2004:11) emphasises that this is not a view held by all researchers and the general public are frequently of the opinion that all dyslexics have a moderate to high IQ. Additionally, there is, in the UK at least, reference to this
condition as being a middle class syndrome, where dyslexia is used as an excuse for a not very bright child (Beaton, 2004:6). It is these topics of intelligence and IQ scores that have often caused confusion in discussions relating to dyslexia, primarily because children of low intelligence often have reading difficulties.

Defining dyslexia is believed by Beaton (2004:10) to be as difficult as measuring intelligence. He suggests that “there is no unique pattern of behaviour that constitutes intelligent behaviour and nor should we expect to find a unique pattern of dyslexic behaviour”. He would rather view dyslexia as “a constitutional weakness that influences the way in which certain tasks are carried out”.

There is popular belief, and also belief amongst some who are active in the field of dyslexia research, that many of the dyslexic population are highly creative (Geschwind, 1982:22; Everatt, Steffert & Smythe, 1999:28-46; West, 1997). However, the number of large-scale studies in this area is small.

There have been in recent years an increasing number of studies that have pointed out that many dyslexics have superior talents in certain areas of non-verbal skill, such as art, architecture, engineering, and athletics. (Geschwind, 1982:22).

In addition to the increasing amount of research into dyslexia, public awareness of this condition has also been raised by several publications. For example, West (1997:101-175) profiles many famous people who have exhibited dyslexic traits. Nevertheless, it should be recognised that the evidence suggesting that these personages may have been dyslexic is by no means complete as, for example, in the case of Albert Einstein. Additionally, the autobiography by the actress Susan Hampshire draws attention to the fact that difficulties with reading and writing do not prevent the learning of scripts (Hampshire, 1983).

That there is controversy surrounding the very existence of dyslexia was recently emphasised in a television programme, entitled ‘The Dyslexia Myth’, broadcast in the UK on Thursday 8th September 2005. During this programme, Julian Elliott, formally an EP and now a Professor at Durham University commented “after 30 years in the field I
have little confidence in my ability to diagnose dyslexia”. The comments made by Professor Elliott led to headlines in national newspapers suggesting that dyslexia does not exist. The controversy, deliberation and discussion that ensued was not only to be found in the media and dyslexia publications. The cover story of the MENSA magazine in December 2005 was entitled ‘The Dyslexia Debate’ and featured an angry rebuttal of the programme by Professor Margaret Snowling one of the UK’s foremost experts in the field of dyslexia (Snowling, December 2005:7-9). The government have also responded to the programme and “rejected the claim that dyslexia does not exist” (http://politics.guardian.co.uk/commons/story/0,9061,1661993,00.html).

3.2 Levels of Dyslexia

There are effectively three distinct ‘levels’ that have been prominent in the study of dyslexia; these are: the biological, the cognitive and the behavioural. These levels are differentiated by the specific characteristics, which are associated with them and depicted in Figure 5.

![Figure 5: A Causal Model of Dyslexia as a result of Cerebellar Abnormality](adapted from Frith, 2002:60)
At the biological level of theory the underlying brain mechanisms of the cerebellum and the magnocellular pathways are considered. The cognitive level includes deficits in working memory, phonological awareness, automatisation and slow processing speed. Lastly, at the behavioural level, poor reading or rhyming deficits are the symptoms linked to this particular theory (Fawcett, 2002:13). Frith (2002:46) takes this classification a step further by acknowledging that the environment may interrelate with these theories. Figure 5 also depicts the interconnectedness of the three levels of dyslexia. Frith (2002:65) believes that these levels may be better understood if the main theories of dyslexia, which are situated within these levels are addressed collectively rather than as discrete theories.

3.3 Theories of Dyslexia

Amidst the aforementioned levels and interrelationships there are currently three main theories of dyslexia, the phonological deficit, the magnocellular deficit and the cerebellar (pertaining to the cerebellum – responsible for balance and co-ordination) deficit. Each of these theories, which may be fitted into the above framework, has an associated research programme that is prominent in the search to unravel the mysteries of dyslexia. Each theory has its own followers whose research has provided varying strategies for both policy and support. These theories are, however, subject to close scrutiny and criticism since no single theory can, as yet, provide a comprehensive demonstrable explanation of the cause(s) of dyslexia. There is also a tendency for theories to overlap thus laying claim to an embracing theory, which could attempt to explain the various causes and complexities of dyslexia. What is clear, however, is that there is some convergence, if only distant, in the theories and if linked they might give a more comprehensive understanding of dyslexia (Reid & Fawcett, 2004:4-8).

The research programmes, which back up these theories, use extensive clinical studies and complex analysis of dyslexic traits. The following sections contain an overview of each of the three main theories, the principal evidence that supports them and the difficulties that may be exhibited. Each theory contains many separate areas of focus, the most prominent of which are also discussed. Some of these areas, for example,
verbal memory and phonological awareness appear to be inextricably linked and have therefore been grouped together.

3.3.1 The Phonological Deficit

In the early days of research into language-based difficulties it was recognised that phonological deficits were a primary symptom of dyslexia (Miles & Miles, 1999:30). It is not surprising, therefore, that this area has undergone the greatest amount of research, is the most widely recognised and is the best understood of the three deficits. As its name suggests, it is concerned with the sound system of a language and is the deficit that the dyslexic child will most regularly exhibit. Given the amount of research that has been undertaken and the exhaustive number of clinical tests that have taken place, Reid and Fawcett (2004:5) are convinced that “There is no doubt that children and adults with dyslexia suffer from phonological deficits (as do other poor readers)”. They also explain that:

Phonological awareness is a meta-linguistic skill involving knowledge about the sounds that make up words, which has been consistently found to be impaired in children with dyslexia, at both the syllable and phoneme level.

Habib (2000:2381) also endorses that it is typical of the dyslexic child to experience difficulty with the use of oral language and the range of skills that are associated with its manipulation. This inability to manoeuvre, in an abstract form, the basic sounds of spoken language is known as lack of phonological awareness. Whilst most children are able to break down words into smaller units well before they can read, dyslexic children are unable to do this even after being exposed to several months of reading and writing.

This deficit leads to the supposition that poor phonological skills may result in poor reading skills, the converse is also true, as poor reading skills correlate highly with poor phonological skills. People with good phonological skills are, as one would expect, generally able to read fluently and manage language-related areas without difficulty (Beaton, 2004:65). In reality, as a consequence of this deficit, most dyslexic children
will find that they have difficulty in reading and spelling. A concise description of the process of learning to read and spell is that:

The task of learning to read in an alphabetic system entails learning to associate letters with their sounds, and reaching an understanding of how sounds can be put together to make words (blending). Conversely, learning to spell requires the child to be able to pull the sounds of spoken words apart (segmentation) and to associate the relevant letters (or spelling patterns) with them. (Hatcher & Snowling, 2002:70-72).

It is important to stress that poor phonological skills do not necessarily imply dyslexia. Diagnosis of dyslexia in those who are unable, without difficulty, to learn the various aspects of the sound system underpinning language and the rules and irregularities connected with English spelling is only possible when this is not due to lack of education, low IQ, aphasia or psychological problems (Farmer, Riddick & Sterling, 2002:1-2).

Difficulties with phonological skills arise from the way in which symbolic language is structured. Evidence from brain imaging has shown that the dyslexic population has a serious problem with the processing of phonemes. Phonemes are speech sounds that make it possible to distinguish one word from another; for example, the sound of the initial consonant enables a distinction to be made between the words pet and bet. It is this distinction that is particularly difficult for the dyslexic population (Murphy, 2003:340).

Reading, in an alphabetic system, requires a person to relate letters (graphemes) to their sounds (phonemes), whereas spelling requires the spoken word to be separated into phonemes, a process known as segmentation, followed by the linking of the graphemes to these phonemes. Dyslexic children usually have difficulty relating graphemes to phonemes and phonemes to graphemes, even at a basic level, which results in difficulties with reading and spelling. When longer words and unseen words are encountered, the problems are intensified, as the mappings between orthography (spelling) and phonology (sound) need to be developed to a high level to ensure that the decoding of words can take place (Hatcher & Snowling, 2002:71-75).
Whilst this deficit does not prevent the dyslexic population learning to understand and be proficient in speech, Murphy, citing Tallal, explains that it "prevents them from associating short bursts of phonemes with their respective letters as they are learning to read" (Murphy, 2003:340). It is the understanding of these grapheme-phoneme conversion rules that makes it possible for children to recognise previously unseen printed words, which they may have heard already or spoken themselves. Children who find it difficult to break down words into their constituent parts will also find it difficult to connect particular sounds with a letter or letter combinations, which will prove detrimental to the acquisition of a phonic reading strategy (Beaton, 2004:66).

The phonological deficit is the most common cause of word reading difficulties in dyslexic children and lies at the heart of dyslexia. Therefore, this impediment has detrimental consequences for children in terms of their successful progression through the educational system. Hatcher and Snowling summarise their understanding of the reading process thus:

In short, learning to read is an interactive process to which the child brings all of his or her language skills. However, it is phonological processing that is the most strongly related to the development of reading, and a deficit in phonological representation that is the source of most dyslexic problems in reading and spelling. (Hatcher & Snowling, 2002:72).

3.3.1.1 Phonological Awareness and Verbal Memory

Dyslexic children are often found to have problems with verbal short-term memory. This symptom of dyslexia appears as a memory deficit and can be related specifically to tasks that require phonological processing. This results in affected children having difficulty holding verbal information in their short-term memory. The consequences of this deficit, as observed in the classroom, are:

... problems following instructions, memorizing lists, carrying numbers and in keeping up with dictation. It has been known for some years that the storage and
maintenance of verbal information over short periods of time depends upon speech-based codes.
(Hatcher & Snowling, 2002:70-71).

This problem with verbal learning and memory is not usually found with non-verbal tasks, for example remembering a visual sequence of events (Singleton, 2002:120). However, the original clinical evidence for this memory deficit came from tests where children designated as readers and non-readers were presented orally with a series of digits, which they then had to repeat. The non-readers recall was less successful, on average, than the readers when recalling sequences of 3 to 5 digits. This led to the conclusion that non-readers have a lower digit span, i.e., their recall of the series of digits is less successful than the readers (Beaton, 2004:72-73). As a measure of reading and potential reading skills, digit span scores seem to be a reliable indicator of a child's likely success at reading. The lower the score the more likely it is that the reader will have difficulty in reading and this seems to be the case irrespective of whether the child is dyslexic or not (Farmer, Riddick & Sterling, 2002:18). These results appear to be conclusive and Beaton (2004:72) conjectures that poor memory span and poor phonological processing skills are associated.

An adjunct to this link, between dyslexics' poor phonological processing skills and impaired verbal memory, is the notion that the phonological deficit may in fact be subservient to a basic auditory deficit. This theory, relating to rapid auditory processing, suggests that dyslexics may have difficulty in the perception of short or rapidly-varying sounds (Ramus, Rosen & Dakin et. al., 2003:842, citing Tallal, 1980). Repercussions of this deficit may result in:

The failure to correctly represent short sounds and fast transitions would cause further difficulties in particular when such acoustic events are the cues to phonemic contrasts, as in /ba/ versus /da/.
(Ramus, Rosen & Dakin et. al., 2003:842).

This approach lends itself to some aspects of the magnocellular theory, which are described next.
3.3.2 The Magnocellular Deficit

It is apparent that whatever tests are performed on dyslexic students, they will nearly always have some form of phonological (retrieval of speech and sounds) deficit. This is unlike the magnocellular (auditory and visual) deficit, which is only evident in about 30% of the dyslexic population (Ramus, 2001: 395). Of the three main theories that relate to dyslexia, the magnocellular deficit is perhaps the most controversial and has generated conflicting views. Skottun (2000: 111-127) is a particular critic where contrast-sensitivity studies (related to colour vision and fine spatial detail in the parvocellular system and responses in the magnocellular system to rapid changes in visual stimulation) have been used to support this theory.

This theory is, however, a main avenue of research and does have a large body of evidence to support it. Ramus (2001: 395) describes the magnocellular theory as being based:

... on the division of the visual system into two neuronal pathways, the magnocellular and parvocellular pathways. This theory holds that the magnocellular system is abnormal in people with dyslexia, causing difficulties in some aspects of visual perception and in binocular control that may cause a reading impairment. In addition, similar impairments in the auditory system are suggested to cause a deficit in processing the rapid temporal properties of sounds, leading to the phonological deficit.

Ramus (2003: 214), citing the work of Stein, 2001 and, Nicholson, Fawcett and Dean, 2001 writes of how the general magnocellular theory may:

... engender auditory, visual and cerebellar/motor deficits. The auditory deficit in turn causes a phonological deficit, thereby triggering the same cascade of events as predicted in the phonological theory. The visual magnocellular deficit is seen as another direct cause of reading problems. In the cerebellar theory, the cerebellar/motor impairment is also thought to independently contribute to phonological and reading problems.
The magnocellular deficit hypothesis suggests an all-embracing sensory insufficiency in auditory, visual and movement processing (Reid & Fawcett, 2004:6). In a simplified explanation of the visual system, there are two main types of cells, which carry the visual signals from the retina to the brain. These are the parvo cells (90%) and the magno cells (10%). The parvo cells are responsible for colour and fine detail, whereas, the much larger magno cells, which deliver their signals up to 10-20 msec faster than parvo cells:

... are important for timing events in the visual world and for detecting changes with time, such as those caused by visual motion, but they do not signal colour or fine detail.


Figure 6 details the magnocellular and linked cerebellar theories of dyslexia (shown in red), the deficits of these theories (shown in green) and the outcomes of these deficits (shown in blue).

Figure 6: A General Magnocellular Theory of Dyslexia.

Sensitivity to visual motion can be tested and a numerical measure of ‘motion sensitivity’ can be derived. The results of tests carried out by Stein, and others, show that dyslexic adults and children have poor motion sensitivity and that the responsibility for this lies with an impaired visual magnocellular system. Orton, who has been mentioned previously, pioneered research into dyslexia in the 1930’s and had persuaded some of his dyslexic patients to donate their brains to science. Examination of these brains, as they became available, has shown impairment of the magnocellular system. Therefore, it can be reasonably argued that an impaired magnocellular system results in poor motion sensitivity. This deficiency has also been shown to correlate strongly to poor reading skills in both dyslexic children and adults (Stein, 2000:110-111). Evidence from clinical studies has also shown that most dyslexics make errors of a visual rather than purely phonetic nature, for example, symmetrical confusion between the letters b and d and visual confusion between the letters m and n, and that this may, in some cases, originate from a purely perceptual impairment (Habib, 2000:2381).

Stein suggests that, in the reading process, the magnocellular deficit exhibits itself, where vision is concerned, due to a lack of stability in fixation related to the necessary saccadic eye movements (the small, rapid eye movements which occur as the eye moves from one word to the next). When reading the eye rests on a particular word for about 300 msecs before saccading to the next one. Whilst retinal images of print are not stable it seems that dyslexics with an impaired magnocellular function cannot compensate for this, therefore the letters of a printed word seem to move around (Stein, 2000:111). A computer simulation demonstrating the visual difficulties, which may be experienced by some of the dyslexic population, can be viewed on the World Wide Web (http://www-staff.lboro.ac.uk/~cvnb1/dyslexsim/).

In addition to these difficulties with visual perception, there may also be difficulties with binocular control, both of which may cause reading impairment. It has been proposed by Stein that binocular instability is a major cause of reading deficit. His evidence has shown that binocular instability may result in both eyes being effectively unsynchronised, resulting in crossing over of the line of sight from each eye thus giving an unstable image of the letters on a printed page. For children affected by this instability, occluding the left eye for both reading and close work relieved this binocular confusion and facilitated their learning to read. After a three month period of having the
left eye occluded it was found that binocular stability was restored and occlusion no longer necessary. From these findings the theory has been advanced that binocular instability may account for the reversal of letters such as b and d, and p and q. (Stein, 2000:112). However, this finding has to be treated with caution since earlier research has suggested that the incidence of such reversals is probably less frequent in practice than was once thought (Miles and Miles, 1999:31).

A more recent theory is the link between supplements of essential fatty acids and improvement in reading. Richardson, Calvin and Clisby et. al., (2000:69-75) have found that there are signs of deficiency of essential fatty acids amongst the dyslexic population. Modern diets tend to be low in essential fatty acids and as the magnocellular system is dependent on these it may be compromised. Stein (2003:1792) recommends that supplements of omega 3, in particular, can improve reading.

3.3.2.1 Visual Sensitivity and Coloured Filters

Mears and Irlen first recognised that coloured filters could help the process of reading for some dyslexic children and Irlen proposed what she called the ‘scotopic sensitivity syndrome’. Initially this idea was criticised, but later research has shown that certain children benefit from either coloured overlays or glasses (Miles & Miles, 1999:66-67).

This aspect of visual sensitivity, tenuously linked to the magnocellular theory, is the processing of depth information and a deficit in this area may be alleviated by the use of coloured filters. Research reported by Everatt (2002:90-91) suggests that the magnocellular pathway is inhibited by the use of red filters as an increase in difficulties is observed when using them, whereas blue filters augment the pathway thus alleviating difficulties. Similarly, research into the effectiveness of tinted glasses has shown that those dyslexic subjects who wear them preferred blue hues. However:

Although these findings are appealing, they are not in accord with the current practice of allowing dyslexic individuals to choose the coloured filter that best suits them. Under such procedures, they often select filters at the red end of the spectrum, which should reduce their reading ability.
The tinting of lenses or the use of coloured overlays is said to reduce glare and distortion, and improve visual comfort for the reader. Whilst dramatic results have been claimed for this form of remediation, the results of research, which tried to control any placebo effect, did not show any reliable improvement (Everatt, 2002:90-91). On the other hand, Miles and Miles (1999:67-70) interpret the results more sympathetically and believe that this benefit is not solely due to a placebo or Hawthorne effect (effect on behaviour due to knowingly being under observation) and that there may be an increased prospect of benefit if there is a history of migraine in the family. They also stress that the use of these lenses or overlays is not a cure for dyslexia, only a section of poor readers are likely to benefit from them, and they are unsure as to why the use of these overlays helps some dyslexic children to read.

3.3.2.2 Auditory Problems

Proponents of the magnocellular theory of dyslexia also include deficiencies in the auditory system as part of their theory. Galaburda and Livingstone (1993:70-82) have found evidence, from post mortems of dyslexic brains, of some disordered development in the auditory system. Stein (2000:113) suggests that like the visual system there is "probably an auditory magnocellular system whose function is to process auditory transients such as those important for phonological analysis, but one must bear in mind that it is not an anatomically separate system as is the case for the peripheral part of the visual magnocellular".

A prevailing theory, based on considerable research, is that reading difficulties in the dyslexic child could be related to speech perception and "the idea that people with dyslexia may have less distinct representations of the sounds of words has been widely accepted" (Frith, 2002:55).

Some, often controversial, research supporting this auditory deficit in the field of temporal ordering (the ability to deal with rapidly changing stimuli) comes from experiments where the dyslexic child was subjected to short bursts of high and low frequency sound of differing durations and of variable intervals. It was shown that aphasic subjects were less able to process information at speed, i.e., the shorter the
duration of the sound the more errors were made. When the experiment was repeated on poor readers in this group the same results were obtained. Subsequently, this work led to experiments where stop-vowels (this is where a consonant is followed by a vowel making sounds such as /ba/ or /da/) were used to test the ability of dyslexic children to discriminate between them. However, these experiments have produced conflicting results (Miles & Miles, 1999:57-62).

That the perception of speech is dependent upon the processing of rapid changes in duration and frequency is described by Beaton, citing Liberman, as: “speech perception requires the listener to respond to resonances that move rapidly up or down in center frequency”. In the case of stop-vowels, discrimination between them “depends upon the ability to detect formant transitions that occur in very short intervals of time, of the order of 10 or 20 msec” (Beaton, 2004:117). A formant transition is “a continuously changing pattern of sound taking place without breaks” (Miles & Miles, 1999:59).

Research in temporal processing has also shown that poor readers may have difficulty in correctly establishing the auditory temporal ordering in which sounds are presented to them. When poor readers were asked to match a sequence of auditory signals to a visual pattern of the same sequence, that is dots separated by large or small spaces dependent upon the time interval, they did not perform as well as the control group (Beaton, 2004:115).

Similar results, from other experiments, confirm that some dyslexic children have difficulty with retaining in their memory the temporal sequence of these events or their perception of them. It is suggested that this fundamental temporal processing problem, “leads to speech processing impairments, which in turn, have a deleterious impact on reading development” (Beaton, 2004:118).

3.3.3 The Cerebellar Deficit

Fawcett and Nicholson, the main protagonists of this theory, believe that the cerebellum (located at the rear of the brain) is implicated in some way with the difficulties that are experienced by dyslexic children. They suggest that the cerebellum is:
... seamlessly involved in almost all actions, whether speech or motor, whether explicit or internalized. It is seamlessly involved in the way we learned to make these actions in the first place, and how we learned to internalize them in the second place. And it is seamlessly involved in making sure that the world remains fixed while we move around. It is an extremely important structure for action, for speech, for learning and for automaticity. The only thing is, it is not accessible to consciousness – the very point is that it allows us to download our skills to a subconscious level, thereby permitting them to proceed more efficiently and in parallel with conscious thought. It succeeds in making extremely difficult tasks seem easy.


They also acknowledge that the cerebellum never works alone in these tasks and point out that there has been little research in the part that the cerebellum plays in cognitive tasks. Their argument is that reading, unlike language, is not a special skill but that fluency in any skill requires it to be automatic, like, for example, driving a car where it takes little or no conscious effort for the skilled driver to competently drive a car. Hence, once a skill has been acquired it can be effectively exercised automatically. They conjecture that this should also be the case for reading where once the skill has been learned it should be automatic (Fawcett & Nicholson, 2004:27-28).

Fawcett (2002:17) proposes that, whilst it has always been known that the cerebellum is involved in learning, new evidence from the US, not linked to research into dyslexia, indicates that “the cerebellum might be involved in language dexterity, via rich interconnections with the language areas of the brain, in particular Broca’s area”.

If a skill is automatic then it is assumed that it can be carried out whilst undertaking another task provided that there is no direct interference. Clinical testing of the ability of dyslexic children to carry out two tasks simultaneously showed that dyslexic children were quite able to balance as well as non-dyslexic children. When these children were asked to balance and carry out another task at the same time, their balance was detrimentally affected, unlike non-dyslexic children who were able to carry out two tasks simultaneously without any impairment in performance. Various other tasks, such as counting and pressing a button, were also tested and these too demonstrated that dyslexic children have difficulty when carrying out more that one task at a time. It was
concluded, “For some reason, dyslexic children had difficulty automatizing skills, and had therefore to concentrate harder to achieve normal levels of performance”. Brain imaging in the 1990’s also showed that the cerebellum was highly active in a variety of skills, which agreed with the belief that the cerebellum was linked to a range of cognitive skills. From this it became evident, “that the cerebellar abnormality was a prime candidate for the cause of the difficulties suffered by dyslexic children”. Testing of dyslexic adults showed that only 10% of normal cerebellar activity was involved regardless of whether the task had been previously learned or was newly encountered. This suggested that dyslexic adults do not activate the cerebellum as it fails to assist them in the way that it assists non-dyslexic adults (Fawcett & Nicholson, 2004:28-29).

Subsequent research has shown evidence of both behavioural and neurological cerebellar abnormality, which could be predicted to cause the ‘phonological deficit’. The causal chain shown in Figure 7 demonstrates the part played by the cerebellar in an embracing theory for dyslexia (Fawcett & Nicholson, 2004:30-31). It has been interpreted, by the author of this thesis, that balance impairment and reduced working memory impact on areas other then writing, reading and spelling.

![Figure 7: An Ontogenetic Causal Chain](adapted from Fawcett & Nicholson, 2004:31)
However, this theory is by no means without its critics. Zeffiro and Eden (2001:512-513) suggest that as the input to the cerebellum comes from many regions of the brain, there might be a problem with the input to the cerebellum rather than with the functioning of cerebellum itself.

Work by Moe-Nilssen, Helbostad and Talcott et. al., (2003:242-243) investigated whether there was a connection between the impaired motor skills associated with dyslexia, and balance control of dyslexics during standing and walking. Whilst the results were not conclusive, it was found that the balance and gait of dyslexic children could be used as a discriminatory test for dyslexia when walking at a fast pace or on uneven ground. The dyslexic child generally took shorter and more frequent steps when walking at a given speed. Additionally, when the data was appropriately adjusted for body size and gender etc., it was shown that gait parameters “may effectively discriminate between children with dyslexia and age-equivalent controls [those without dyslexia] with up to 85% accuracy”.

3.3.3.1 Motor-Skills

The cerebellar deficit should, according to a study undertaken by Nicholson and Fawcett (1990:159-182), be evident in trials that test the motor skills of dyslexic children. In a later study investigating the relationship between motor control and phonology in dyslexic children, Ramus, Pidgeon and Frith (2003:712-722) tested a group of 8-12 year olds to examine the automaticity/ cerebellar theory of dyslexia. In this investigation, a battery of tests was given to both the dyslexic and control groups. The first assessments were of a phonological nature and these were then followed by four motor skill tests, which are assumed to use the cerebellar function and were taken from the studies undertaken by Nicholson and Fawcett. The first motor skill test was a finger to thumb exercise, which involved rotation of the hands. The second involved threading beads onto a string as quickly as possible. The third was a postural stability test, which required the subjects, who had been blindfolded, to remain as still as they could when a push was administered to their lower back. The final test was a time estimation exercise where the subjects were asked to say whether the second of two tones presented to them was longer or shorter than the first one. Not surprisingly, the
phonological tests showed that, in general, the dyslexic subjects had serious problems in this area. It was also confirmed that, on average, dyslexic children are “significantly impaired on motor control tasks” although there was not any evidence of a time estimation deficit. In their conclusion they could only agree with the main body of research, which has found “that a phonological deficit directly causes the reading impairment in dyslexia”, rather than it arising from a “more general cerebellar/automaticity/motor impairment”.

This inability to find conclusively a causal link between the cerebellar and automaticity, motor impairment and phonological processing has led Ramus to the opinion:

Dyslexia research now faces an intriguing paradox. It is becoming increasingly clear that a significant proportion of dyslexics present sensory and/or motor deficits; however, as this ‘sensorimotor syndrome’ is studied in greater detail, it is also becoming increasingly clear that sensory and motor deficits will ultimately play only a limited role in a causal explanation of specific reading disability.

(Ramus, 2003:212).

3.4 Summary of the Theories of Dyslexia

In summary, the dyslexic population will exhibit deficiencies in language processing and may also have poor balance, poor automatization, poor short-term memory and visual difficulties, amongst many other symptoms, all of which can be related to one or more of the three main theories that have been described. What is certain is that each and every one of them will, to a greater or lesser extent, exhibit a phonological deficit, which at the outset of the educational process, causes dyslexic children the most difficulty in successfully learning to read, write and spell. This phonological deficit will, potentially, at least, hinder progress since reading and writing are the cornerstones of literacy and this is the medium through which most subjects are taught.

Whilst there is not yet a single theory that can fully explain the cause(s) of dyslexia, there are now some aspects of convergence between the theories, despite the controversy and contention that often surrounds them. However, it is important to
understand that the theories are trying to explain dyslexia and are not, necessarily, attempting to provide remedial measures or indeed find a cure for it. The theorists are identifying and correlating the numerous characteristics of dyslexia in an endeavour to gain a better understanding of the condition. This should then lead to the implementation of better teaching and learning strategies to help the dyslexic population cope with the non-dyslexic environment in which they live. It is also apparent that whilst all dyslexic children show some evidence of the phonological deficit, they are likely to exhibit different deficiencies when undertaking the various tests, which support the three different theories. This suggests that it is unlikely that any one theory will be able to describe the whole dyslexic population.

Reid and Fawcett (2004:4-5) do not believe that the theories are incompatible but emphasise that “our ultimate aim must be to link from the brain to behaviour, to allow a more sophisticated diagnostic system based on the specific difficulties each child encounters”. Moreover, Fawcett (2002:13-14) believes that there should be a clear understanding of the causes, symptoms and treatment of dyslexia, to enable a test for early diagnosis to be developed, rather than waiting until a child has failed to learn to read.

The work of Moe-Nilssen, which has been discussed earlier, raises the issue of why gait characteristic tests are not being used to identify children who might be dyslexic before they experience learning difficulties. However, as Stein, Talcott and Walsh (2000:210) point out:

One of the problems that dogs the study of dyslexia, and is really quite unnecessary, is the common tendency of researchers defending their particular turf to assume that physiological and psychological explanations must engage in head on competition and be mutually exclusive.

Surely it must be time to cut the Gordian knot and concentrate on what must, without doubt, be the ultimate goal – to establish the cause(s) of dyslexia and to find some form of treatment that will either limit or even eliminate its effects.
3.5 Statistics for Dyslexia in Higher Education

Singleton (1999:1-18) states that dyslexia occurs in about 4% of the population, the incidence of dyslexia in HE is estimated at between 1.2% and 1.5% of all students and the incidence of dyslexia by gender is in the ratio of male: female between 3:1 and 5:1. Of these numbers, 57% are already known to be dyslexic on entry to university. However, there is now some doubt about the difference in incidence of dyslexia by gender. Brazeau-Ward (2005:25) citing Lyon reports that research has shown male/female ratios to be the same and explains, “More males have usually been identified by teachers in school because of their tendency to be more rowdy and active than females”.

As mentioned at the beginning of this chapter, the number of dyslexic students in HE is growing. The percentage of the student population stating that they are dyslexic on entry to university is also rising, in 1994/95 it was 0.47%, in 1998/1999 it was 1.10%, in 2001/2002 it was 1.84% and the latest available figures for 2004/2005 show 2.18% (HESA in the UK; http://www.hesa.ac.uk/holisdocs/pubinfo/stud.htm). In Chapter II it was pointed out that many dyslexic people are believed to be gifted in a visually creative way therefore, given the above figures, it is extremely likely that most engineering courses will contain a dyslexic student or students.

Section 3.7.2 details the findings from the data collection of the number of students at Loughborough University who are diagnosed as dyslexic after commencing their undergraduate studies. Members of support units at other universities have confirmed that there has been a rise in the number of students who are diagnosed as dyslexic after entering university. In particular, Cardiff and Hull Universities have reported a growth in the number of dyslexic students who are diagnosed as being dyslexic after entering university but due to the way their data is collected they have not been able to provide a detailed breakdown of numbers.

In the UK, disabled students are, if eligible, entitled to claim the Disabled Students’ Allowance (DSA). Pumfrey (citing Laycock, 1996) draws attention to the number of dyslexic students claiming the DSA compared to students with all other disabilities:
From being almost unheard of in 1990 [in higher education], dyslexia grew to outnumber all other disabilities by 1994. Today it is in danger of being so overwhelming in its influence that the rules may be changed simply to deal with it alone despite the potential effects on all other disabilities. Dyslexia accounts for about 60% of all Disabled Students' allowance bids, but constitute almost 100% of the doubts, rumours and objections from the various sectors responsible for operating the system.


3.6 Dyslexia Diagnosis and Support at Loughborough University

Within Loughborough University there is widespread information on dyslexia. Checklists, detailing many possible manifestations of dyslexia, with contact names and addresses, are prominently displayed throughout the campus and information is available at http://www.lboro.ac.uk/disabilities/pages/practices-dyslexia.html. The ELSU run weekly workshops for dyslexic students and the unit in the university known as Professional Development raises awareness of dyslexia (relating to its recognition, the difficulties that may be encountered and support that may be required) through their provision of several short courses each year. Additionally, the university has been proactive in developing a dyslexia-friendly environment.

3.6.1 Dyslexia Diagnosis at Loughborough University

Once a student has made contact with a member of the Disabilities and Additional Needs Service (DANS), the ELSU or the MLSC and partaken in a discussion appertaining to dyslexia, this is then followed by a more in-depth interview conducted by a member of the ELSU. If, after this, the student wants to proceed, a Dyslexia Adult Screening Test (DAST) is administered to determine whether the student is considered likely to be dyslexic or not. Students who have either a positive or marginal result are then, if they wish, referred to an EP. A mean ‘At Risk Quotient’ (ARQ) of 0.7 – 0.9 is a mild indicator of dyslexia whereas an ARQ of over 1 is a strong indicator of dyslexia.
In the case of UK students, Loughborough University pays for this assessment.

The EP will determine whether the student is dyslexic or not and produce a detailed report, which includes the test results and recommendations such as extended time for examinations, technological support, or the provision of one-to-one support. A member of the DANS will then write a ‘Needs Assessment’, based on the report from the EP and the course requirements of the student concerned. Assistance is given to the student with application to their LEA to obtain the DSA, which funds the cost of any additional requirements that have been recommended in the report.

Most universities in the UK have specialist units, which are responsible for students with disabilities and special needs. At Loughborough University the DANS provides support which includes external assistance such as liaison with social services and internal assistance such as ensuring the suitability of accommodation. The ELSU assists International Students with study skills and English language problems. It also assists UK students who are having problems with the language needed for their studies and provides support with report writing, time management, increased library loan time and the development of compensatory strategies.

3.6.2 Dyslexia Support at Loughborough University

Once diagnosed as dyslexic, students at Loughborough University have access to a range of general and mathematics-specific support, which is given by dyslexia-dedicated members of staff. If an EP recommends one-to-one support for a student, then prompt discussion of their immediate needs is undertaken and either a member of the ELSU or the MLSC quickly implements suitable support, tailored to the particular needs of the student. The ELSU provides one-to-one support with the development of compensatory strategies, the structuring of essays, time-keeping and revision techniques. The MLSC arranges for the provision of one-to-one mathematical or statistical support when needed. Dyslexia-dedicated members of staff give this support. An example of this is when it is believed that dyslexia is impeding, or has the potential to impede, progress in the mathematical or statistical elements of a student’s course. For
example, if a student is undertaking a statistics module, then it might reasonably be assumed that in addition to any computational problems, difficulties will also be experienced with the lengthy text that will be encountered and, for those students who encounter visual disturbance, with the use of statistical tables. Unfortunately, this form of specialist mathematics support does not seem to be available in the majority of universities in the UK; details of the survey that has been undertaken and the findings from it are given in Chapter IX, section 9.4.3.

The ELSU have introduced weekly workshops, during term time, for dyslexic students. These sessions not only provide help with specific pre-advertised topics, but also offer opportunity for students to meet each other to discuss difficulties and share ideas.

Students at Loughborough University have been pro-active and formed the Students With Additional Needs (SWAN) club. This group is well advertised around campus and is also accessible at http://www.lboro.ab.uk/disabilities/pages/SWAN.htm. In addition to social activities, they also liaise with the DANS and other departments within the university, in an endeavour to highlight concerns and queries that are raised by students, make suggestions regarding areas of support they feel would be beneficial and draw attention to any delivery procedures that are causing difficulties.

For those students who have been awarded extra time for examinations, these examinations are now held in separate venues or in venues where the examinations taking place correspond time wise to the extra time examinations. This is to avoid the disturbance that would ensue with a large number of students leaving the room whilst others were still working. Additionally, in these extra time examination venues squared paper is available on request.

Trott and Beacham are currently investigating different 2-line scientific calculator models to determine those that are most easily used by dyslexic students. They have found that certain key/colour combinations on calculators pose difficulties to some dyslexic students (http://mec.lboro.ac.uk/). A list of calculators that are approved for examinations has been published internally by Loughborough University and this has taken into account the findings of Trott and Beacham.
3.6.2.1 Choice of Font

Sans serif font is now used at Loughborough University for all text in examination papers. The usage of sans serif font for dyslexic students is widely recommended, however, it must be borne in mind that these recommendations are based on the widespread personal experiences of support tutors rather than controlled research.

The issue of “To serif or not? A question of fonts”, has been raised by Tomlin (2003:1, 5). She reports on the responses received to this question, which was posted on two British email lists in an endeavour to obtain research references on issues surrounding readability. The responses to this query have been collected into an unedited paper, which is available from alison.tomlin@kcl.ac.uk. The question was posed generally and not specifically directed towards the requirements of the dyslexic population; nevertheless, some of the responses referred to the best fonts for dyslexics. The replies were numerous and somewhat contradictory but did not produce any evidence of research into the best fonts for dyslexic students. Regarding dyslexic students, Helen Sunderland from Southbank University responded that whilst she was not aware of any research, “the commonly held view amongst dyslexic specialists is that fonts WITH serifs are the easiest to read because the little bits at the top and the bottom of letters hook the eye and help differentiate all those very bland circles and lines”. Margaret Hemmington, who is prominent in the field of dyslexia, holds the opposite point of view. She explained, “The readability of text for dyslexic students regularly includes the preference for non-serif fonts. You may call this only folk knowledge but there are masses of tutors working with dyslexic students who have found a whole range of factors affecting accessibility”.

The BDA (http://www.bdadyslexia.org.uk/extra352.html) recommends that fonts should be sans serif, rounded and replicate cursive writing. However, this is not true for the whole of the dyslexic population. Stacey (1997:115) writing of her personal experience of dyslexia explains, “My spelling and reading are font dependent. I see spelling errors in Times Roman and I read more fluently in Times Roman”.

It may be the case that institutions that have changed their handouts and examination papers to sans serif font may be disadvantaging some students.
3.7 Dyslexia Records at Loughborough University

The DANS maintain a cumulative record of the number of students who register on application to the university that they are dyslexic, who report that they are dyslexic at the commencement of their university studies and those who are diagnosed as dyslexic after entering university. Whilst the data included a departmental breakdown, there was not, unfortunately, any indication as to the number of students who had been diagnosed as dyslexic after commencing their studies.

Students who believed that they might be dyslexic initially approached, or were advised to approach, the ELSU to discuss their difficulties. Fortuitously, in 1999, a member of staff in this department initiated the system of recording student visits in an A4 book. These records included student name, course of study, year of study, date of attendance and reason(s) for attending. Some students were attending because they suspected that they might be dyslexic, others were attending for support on either an occasional or regular basis. The outcomes of interviews, the DAST and EP appointments were also recorded. It was these handwritten records that enabled the number of students who had been diagnosed as dyslexic after commencing their undergraduate studies to be determined.

3.7.1 The Data Collection

During the academic year 2003/2004, a member of the ELSU provided photocopies of the manually recorded data, excluding the columns containing the students' names and ID numbers. Using an Excel spreadsheet, the relevant data (date diagnosed, year and course of study) from the photocopies was entered into it. A copy of this spreadsheet was forwarded to the ELSU; a member of staff then used an adapted version of this during the academic years 2004/2005 and 2005/2006 to record student visits. Data was obtained from the DANS at the end of June 2004, June 2005 and July 2006, which showed the total number of dyslexic students registered on foundation, undergraduate, taught postgraduate (Masters) or research postgraduate courses at Loughborough University during the academic years commencing 2002 to 2005 inclusive.
The method of data collection from the ELSU was an extremely time consuming and protracted task, nevertheless; when taken in conjunction with the information provided by the DANS it enabled the number of students diagnosed as dyslexic after commencing their undergraduate studies and those known to be dyslexic prior to commencing their studies to be determined. However, it must be noted that these figures are approximate.

3.7.2 Results of the Data Collection

Statistics from Loughborough University (2003) disclosed that in the academic year commencing October 2002, 3671 students were registered in the Engineering Faculty on undergraduate, taught postgraduate (Masters) or research postgraduate courses at Loughborough University. The ratio of male: female students at Loughborough University in 2003/2004 was, undergraduates 1.6:1.0, postgraduate courses 2:1 and postgraduate research 2.5:1.0. These numbers have remained relatively stable during subsequent academic years.

The figures from the DANS showed that there were 33 students in 2002/2003, 53 in 2003/2004 and 78 in 2004/2005 on engineering based undergraduate, taught postgraduate (Masters) and research postgraduate courses at Loughborough University who had registered on application, notified the DANS on arrival or been diagnosed as dyslexic after entry. From the information from the ELSU, it was determined that 58 Engineering students were diagnosed as dyslexic after their arrival at university, 10 in 2002/2003, 15 in 2003/2004 and 33 in 2004/2005. These figures are shown in Table 2.

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<tr>
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<tr>
<td>Dyslexic on entry</td>
<td>23</td>
<td>38</td>
<td>45</td>
</tr>
<tr>
<td>Diagnosed as dyslexic after entry</td>
<td>10</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>53</td>
<td>78</td>
</tr>
</tbody>
</table>

Table 2: No. of Dyslexic Engineering Students at Loughborough University
The numbers for the academic year 2005/2006 also show an increase but have not been included as there are some students with a marginal or positive DAST waiting to see an EP and other students who have seen an EP but the records have not yet been updated or in some cases the reports not yet received.

3.8 Summary of Dyslexia in Higher Education

In summary, approximately 4% of the population is dyslexic. The number of students stating that they are dyslexic on arrival at university and the number being diagnosed as dyslexic after commencing their undergraduate studies are both rising.

As mentioned in Chapter II (section 2.4) dyslexia is not just related to poor spelling, it includes shortcomings with working or short-term memory, visual disturbance and organizational weakness. Mathematics also requires the learning of a symbolic language and Greek characters. Difficulties are frequently encountered not only with notation but also with multi-stage mathematical operations (as mentioned in Chapter II).

With the growth of the number of dyslexic students entering HE and the growth of those being diagnosed as dyslexic after entering HE, it is imperative that sufficient and adequate support mechanisms are introduced to comply with the SENDA, which requires institutions to be pro-active in addressing the needs of students with disabilities. Whilst awareness is growing and research reports forthcoming, there is a dearth of practitioner-based research in the HE setting and that relating to mathematics is almost non-existent. This thesis endeavours to address this shortcoming.
Case Study was viewed as an appropriate method for the majority of the planned educational research into dyslexia, mathematics and mathematical support included in this thesis. A review of texts, appertaining to educational research methods, determined that it was, indeed, suitable for the research being undertaken (for example, Anderson, 1988; Bogdan & Biklen, 1982; Burns, 2000; Cohen, Manion & Morrison, 2000; Robson, 2002). An in-depth review of this method was then undertaken to ensure that the research to be undertaken would be of an exemplary nature and any conclusions drawn from it would be valid. An outline of case study is given in section 4.1, further information on this research method is included in Appendix H. Sections 4.2, 4.3 and 4.4 describe the exploratory case studies, the one-to-one cases studies and the explanatory case studies respectively. Section 4.5 describes the MLSC case study.

4.1 Case Study as a Research Method

Case study is a non-experimental, in-depth research method. In 1975 at a conference held in Cambridge, the proceedings of which were edited by Helen Simons and published as a book entitled ‘Towards a Science of the Singular’, Adelman, Kemmis and Jenkins (1980:48) succinctly describe case study as:

An umbrella term for a family of research methods having in common the decision to focus on enquiry around an instance.

In case study, the researcher lays down research questions regarding a specific instance and then formulates hypotheses before proceeding to collect evidence systematically. The ‘instance’, which is more usually referred to as the unit of analysis, may be, for example, a person, a group, an organization, an innovation or a piece of legislation. The evidence may be collected in many ways: such as by interviews, documents and observation. Several different methods will be used in any one case study to provide cross-checking (triangulation) of the data. Analysis of the data is then undertaken to
provide evidence in support or rebuttal of the hypotheses. The case study concludes with the evidence presented in a case study report (Yin, 2003). The above is a very brief outline of a method involving many stages, all of which require detailed planning, rigorous collection of data, exemplary record keeping and difficult analysis; and the whole process must be conducted without any bias on the part of the researcher.

The following sections give details of the modus operandi for the case studies undertaken in this research. The case study reports are given in Chapters V, VI, VII and X respectively.

4.2 The Exploratory Case Studies

From the review of case study as a research method, it was considered that this method was highly appropriate for the research being undertaken, by the author of this thesis, into dyslexia and mathematics, and the MLSC. The review of literature that has been undertaken (see Chapter II) revealed that the problems encountered in mathematics by dyslexic students in HE had not undergone any significant research. The exploratory case studies (see Chapter V) were undertaken during the academic year 2003/2004 to investigate whether there were any problems encountered in mathematics by students who had been diagnosed as dyslexic after entering HE. The purpose was to determine if there is any evidence to suggest that dyslexic students are impeded in their learning and understanding of mathematics as a direct result of their dyslexia, to determine whether there is evidence to justify a larger and more searching study, and to provide training for the researcher in case study research. This research is exploratory in nature and exploratory multiple-case studies have been used.

The exploratory studies are holistic (self-contained), i.e., without sub components; the unit of analysis could be a student or students; here it is students, as multiple-case studies are being undertaken. The case studies all directly replicate each other; they involve students who are registered in mathematics, science or engineering departments who have been diagnosed as dyslexic after entering HE. These case studies ask only one question, namely, 'What problems, if any, do students who have been diagnosed as dyslexic, after commencing their undergraduate studies, experience in mathematics?'
They do not necessitate an hypothesis and analysis is not difficult. In addition to the purposes already mentioned, these studies will also provide an opportunity to reconsider and scrutinize the research to determine if a lack of rigour has been evident at any stage.

A request was made to a member of the ELSU asking for students diagnosed as dyslexic after commencement of their undergraduate or postgraduate studies to participate in this research. These students were requested as they would not previously been taught any compensatory strategies. The selection criterion was that the students must be registered in the faculties of science or engineering. A member of the ELSU approached four students who were all willing to participate. One of these students also asked a friend, who matched the required criteria, to participate. This student agreed and became part of these exploratory studies. The researcher directly approached another student, registered on a postgraduate course, as she was aware that he had been diagnosed as dyslexic whilst reading for his degree in mathematics. This student also agreed to participate in the research.

The research design for these exploratory case studies was not difficult as only one question was being asked and the research involved only one investigator. The research design (including the purpose of the studies), case study protocol, criteria for judging the quality of the research design and the interview questions are included in Appendix A. Written permission was requested, from all the participating students, to permit data to be obtained from interviews, from reports provided by the EP (who determined that the students were dyslexic) and from members of staff who knew them. This information would enable triangulation of the data. The consent form also informed the participants that the findings might be published in journals and conference proceedings in addition to this thesis. The interviews, during which notes were taken, followed a semi-structured format. As recommended by Cohen, Manion and Morrison (2000:121-122) the same questions (two questions were not asked to the final two students as it became evident that the answers to these questions may be socio-economic dependent and therefore they are not included in the analysis), presented in the same order were posed to all the participants and no leading questions were included. Each case study has been individually filed under the given pseudonym, with the original notes included, and this raw data is available for inspection.
The strategy for analysis was to use the theoretical proposition that led to the studies being undertaken. This was: that students who have been diagnosed as dyslexic after commencing their undergraduate studies might experience problems in mathematics. The analytic technique employed was that of cross-case synthesis, which according to Yin (2003:109-136) is specifically linked to the analysis of multiple cases. This analysis involved recording, from each case study, the main difficulties that were encountered.

4.3 Case Studies of the Students Receiving One-to-One Support

One-to-one mathematics support was provided to four students (referred from the ELSU) during the three years of this research to enable any difficulties that were encountered by them to be witnessed and suitable forms of support to be developed and tested. The provision of this support also provided an opportunity to correlate witnessed difficulties with the reported difficulties in the earlier studies. Two case studies are reported in this thesis (see Chapter VI). One student received support for two years, and the other for one semester. Each student received one hour of mathematical support per week. It was through working closely with the student who received help for two years that some of the questions for the explanatory studies (see Chapter VII) were developed. As in the previous case studies, the unit of analysis is the student.

The research design, case study protocol, criteria for judging the quality of the research design and the interview questions are included in Appendix B. For the two students with whom case studies were undertaken, data was obtained from the interview questions, from discussions (during which notes were taken), from observation of their difficulties, from reports provided by the EP (who determined that the students were dyslexic) and from other members of staff who had worked with these students thus providing triangulation of data. Written permission was again requested and obtained. One student, Russ, who was supported with his mathematics modules for two semesters had mental health difficulties, in addition to being dyslexic, and it was considered that for him to participate in the studies might prove stressful. For this student, only the mathematical difficulties that were witnessed are reported. The other student who received support was found to be dyspraxic and his difficulties were of a different nature; the support that he was given was of a more general nature. He withdrew from
his course, electing to re-commence it the following year and subsequently received support from another member of staff. The two case studies have been individually filed under the chosen pseudonyms, with the original notes included, and this raw data is available for inspection.

The strategy for analysis was to use the theoretical propositions that led to the studies being conducted. These were: that undergraduate dyslexic engineering students are impeded in their learning and understanding of mathematics as a direct result of their dyslexia, they might be disadvantaged in particular topics, by the delivery of material and by assessment procedures. The analytic technique employed was that of cross-case synthesis. The analysis involved recording, from each case study, the main difficulties that were encountered, in categories determined from the hypotheses that were included in the research design.

4.4 The Explanatory Case Studies

The explanatory studies (see Chapter VII) were undertaken during the academic years 2004/2005 and 2005/2006 to determine how dyslexia impedes the learning and understanding of mathematics and how dyslexic students are disadvantaged in their learning and understanding of mathematics by current practices of material delivery and examination procedures within Loughborough University. As in the earlier exploratory studies (Chapter V), the unit of analysis is the student. For these multiple-case studies it was decided to tighten the criteria for eligibility and focus on dyslexic undergraduates reading for degrees in engineering who had been diagnosed as dyslexic after entering HE. This decision was primarily made to ensure that the students participating in the studies would be undertaking mathematical modules with a similar content. It was also decided to include a greater number of students in these studies to further ensure that the findings could be generalised. A control group with an equal number of non-dyslexic engineering undergraduates were also interviewed.

A request was made to a member of the ELSU asking for undergraduate engineering students, who had not participated in the exploratory studies, and had been diagnosed as dyslexic after commencement of their studies, to participate in this research.
Unfortunately only one student volunteered despite several approaches being made by the aforementioned member of staff. It was deemed necessary to offer a small honorarium to encourage student participation; the student who had already participated also received this honorarium. To obtain a sufficient number of students it was considered necessary to change the criteria for eligibility. Students who have been diagnosed as dyslexic prior to entering HE have been included in this study. As this modification only involved the selection of different cases and modification of the research design it does not jeopardise the rigour of the study (Yin, 2003:55).

The request for student participants was also made to members of staff providing one-to-one mathematics support to dyslexic students. Additionally, the author of this thesis described the research being undertaken to all students attending her tutorial sessions during both semesters in the academic years 2004/2005 and 2005/2006 and asked for volunteers. In total, 12 dyslexic students and 12 non-dyslexic students participated in the explanatory studies. The findings from the interviews with the non-dyslexic students enabled a comparison to be made between dyslexic and non-dyslexic participants in their approaches to study and revision, and also the particular topics where difficulty was encountered. This control group would also increase internal validity, as it would minimise the risk of non-dyslexic difficulties (amongst the dyslexic students) being attributed to dyslexia.

The research design, case study protocol, criteria for judging the quality of the research design (for the dyslexic students) and the interview questions (for the dyslexic and non-dyslexic students) are included in Appendix C. For the dyslexic students, data was again obtained from interviews with the students, from reports provided by the EP (who determined that the students were dyslexic) and from members of staff who had worked with the students, thus providing triangulation of data. Written permission was again requested and obtained from all the participating students. One dyslexic student did not accede to the request to view his EP report. The non-dyslexic students were interviewed only. The interviews, during which notes were taken, followed a semi-structured format, each case study being individually filed under the given or chosen (in these studies the students were given the option to choose a name) pseudonym, with the original notes included, and this raw data is available for inspection.
The strategy for analysis was to use the theoretical proposition that led to the studies being conducted. This was, that undergraduate dyslexic engineering students are impeded in their learning and understanding of mathematics as a result of dyslexia and might be disadvantaged in particular mathematical topics, by the delivery of material and by assessment procedures. The analytic technique employed was that of cross-case synthesis. The analysis involved recording, from each case study, the main difficulties that were encountered in categories, which were determined from the hypotheses that were included in the research design. In addition, the findings from these studies will be, where possible, matched to those from the one-to-one case studies. Any agreement of findings between the studies will increase validity.

4.5 The Loughborough MLSC Study

The case study of the MLSC (see Chapter X) was undertaken to investigate the effectiveness of the MLSC, whether the support it provides is suitable for dyslexic students and whether the Centre is really necessary. The MLSC is a unit of analysis but embedded units are the students who use the Centre and the staff who work in it.

Prior to the opening of the MLSC in 1996, there had been some support provided by a member of staff on one afternoon per week. Details of this precursor to the MLSC were obtained by interviewing those staff who were involved with, or realised the need for, mathematics support. Interviews were undertaken with Mr Simpson, a retired lecturer, who provided this early support and with Professor Pugh who had, at that time, been Head of the School of Mathematics and was involved with the implementation of the MLSC.

In order to determine the effectiveness of the MLSC, data has been obtained through two distinct channels:

i) The author of this thesis observed the students using the Centre and the staff who work in the Centre. This two-semester observation was undertaken in order to determine if there are problems that are frequently experienced by students using the Centre, if these students are being successfully helped to resolve their mathematical difficulties
and if these difficulties are of a different nature to those experienced by dyslexic students. Additionally, it enabled the attitudes of staff working in the Centre to be observed and also showed whether these members of staff were able to recognise and address any fundamental underlying weaknesses in mathematical background that may be causing problems for students attending the Centre.

ii) A census form was distributed to all academic and academic-related staff in the School of Mathematics and a similar questionnaire was also made available to students who had frequently used the MLSC. The questions that were contained in the census form and the questionnaire were numerous and wide-ranging. In addition to the research being undertaken for this thesis, it was recognised that such lengthy questionnaires could not be distributed again in the near future. At this time there was a possibility that extension to the MLSC might take place and a new Centre might also be opened in the centre of the campus. With this possibility, many questions, relating to areas outside of the research being undertaken by the author of this thesis, were included in both the staff census forms and the student questionnaires. The responses to these questions have been taken into consideration in the design of the new Centre and in the extension of the existing Centre, which are currently being undertaken.

Two forms of survey are described by Burns (2000:566-571); the census, which incorporates 100% of a population, and questionnaires, which are a sample survey and should be representative of the population. These surveys may include closed questions, open-ended questions and scale questions. In the design of the questions it is important to avoid ambiguity, imprecision and the making of assumptions (Bell, 1993:77). It is also important to avoid negatively posed questions, which may be difficult to understand and, to avoid jeopardising the results, leading questions must be avoided (Robson, 2002:245-246). With closed questions there is no undue discrimination arising from how expressive and eloquent the respondents are (Wilson & McLean, 1994:21). However, Oppenheim (1992:115) emphasises that if closed questions are used, care must be taken to ensure that the given categories are exhaustive. It is also important to ensure that categories are mutually exclusive (Robson, 2002:244). For closed questions, Burns (2000:578-579) considers it to be important to include a ‘don’t know’ option, as this may also prove informative if many of the respondents answer in this way. Furthermore, scale-type questions should be balanced around a midpoint with the boxes
for answers arranged vertically rather than horizontally to reduce errors being made by respondents. Cohen, Manion and Morrison (2000:255, 262) mention that thought must be given to ways of checking the validity of responses. This may be done through introducing a checking system i.e., by asking different questions on the same topic. They also explain that open-ended questions avoid the limitations of closed questions, as these provide freedom for the respondents to explain and describe situations in their own words. This gives the rich detailed information that is characteristic of qualitative data and, for small-scale research, these questions are particularly enlightening. Nevertheless, Robson (2002:234) points out that open-ended questions are time-consuming to analyse.

All the reviewed literature on questionnaire design stressed the importance of conducting a pilot study. Burns (2000:579-580) writes that this provides opportunity to discover any questions that might cause confusion or be difficult to answer. Bell (1993:84) adds that it provides opportunity to gain vital feedback and Cohen, Manion and Morrison (2000:260) emphasise that it provides opportunity to check many features of the questionnaire, such as the validity of questions and the time needed for completion.

To increase response rates, the questionnaire should be designed to be appealing; the pages should not be overcrowded, there should be plenty of space allowed for answers and a thank you to the potential respondents should be included (Burns, 2000:574-575, 580; Cohen, Manion & Morrison, 2000:258-259). Bell (1993:85-86) recommends that a deadline for responses should be stated in the questionnaire, an envelope for its return should be included even if this is to be via an internal mail system, and the questionnaires should be personally delivered if possible. Burns (2000:575) recommends that the name and address of the person to whom the questionnaire is to be returned is included on the questionnaire even if an envelope for its return is included. Incentives may be used and Robson (2002:249-250) believes that these are most effective if they are distributed with the questionnaire as opposed to entering respondents’ names into a prize draw and should be a token gesture such as a ballpoint pen rather than a payment. Furthermore, response rates may be increased by including a covering letter, which clearly describes the aims and importance of the study, assures confidentiality and encourages participation. Follow-up and further follow-up of non-
respondents is recommended, with the importance of the questionnaire being emphasised and a further copy of the questionnaire included. There is some disagreement as to what constitutes a good response rate; Cohen, Manion and Morrison (2000:262) advocate that one should be satisfied with a 50% response rate whereas Robson (2002:251) believes that a 90% response rate is desirable to avoid biased estimates being made.

The staff census forms initially consisted of 18 sides, split into 6 sections, and contained a mixture of closed and open questions. The closed questions consisted of dichotomous items that required a yes or no answer and items offering a selection of options from which to select an answer. The open questions asked for opinions, ideas and reasons to be stated. The student questionnaires contained many similar questions, some questions asked from the opposite perspective and some different questions, and consisted of 14 sides.

A pilot study was undertaken with the census form. There were several points raised, namely: there was insufficient space in the boxes provided to record ideas and comments, the form was too long and would produce a very low response rate, the data would be difficult to analyse, and staff would not be able to answer questions such as “Regarding the previous question, how do you think most other academic staff in the department feel about this issue?” As a result of this pilot study, more space was provided for the recording of answers and some questions were removed to reduce the size to 16 sides. It was considered that as members of academic and academic-related staff in the School of Mathematics hold the MLSC in high regard and, as the researcher was personally known to most of these staff, there would be a good response rate. It was also decided to retain the questions that asked for opinions on how colleagues feel about the issues raised in the form, as considerable discussion takes place between members of staff about incoming students, their qualifications and their attendance at lectures and tutorials. These beliefs were well founded, 29 out of the 33 staff who received a census form returned it, and the vast majority of those completing the form answered the aforementioned questions relating to colleagues’ opinions that it had been decided to retain.
The staff census forms were delivered to each member of staff by the author of this thesis, with a personalised covering letter and an addressed envelope for returning the form, during the first semester of the academic year 2004/2005. An incentive of a prize draw was detailed on the first page of the census; it was considered that with 33 eligible staff and three prizes available it would be more tempting than a ballpoint pen. Indeed, several members of staff contacted the author of this thesis enquiring as to how many responses had been received, as they wanted to work out the odds of winning a prize. A response rate of 87.8% was obtained.

The student questionnaires were made available to frequent attendees of the MLSC during the second semester of the same academic year and again a prize draw for the respondents was offered as an incentive. The response rate is estimated at 36.9% and details of how this estimate was determined are included in Chapter X.

It was considered that the lengthy questionnaires might prove daunting for dyslexic students and there would be a low response rate from such students. This aspect has not been ignored; in the explanatory studies, that have been described previously, questions appertaining to usage of and effectiveness of the MLSC were posed to the dyslexic students.

The research design, case study protocol, criteria for judging the quality of the research design, census forms and questionnaires are included in Appendix F. Analysis of the data contains a mixture of qualitative and quantative methods. Bell (1993:128-149) explains that data must first be recorded then analysed and the findings interpreted. The researcher may have pre-determined some categories from questions posed but inevitably additional categories will emerge as analysis continues. Also described are many ways that the findings may be displayed such as tables, grids, charts and graphs. Researchers are also warned to avoid complicated statistics unless competent in this area and it is pointed out that it is possible to produce a good report without the use of statistics if the questionnaire has been well designed. All data from the census forms and questionnaires were first entered into a spreadsheet in order to preserve all the original information, to make collation more manageable and to determine whether there were any responses that were gender or age dependent. Information from the open questions (section 5 of the forms) has been coded and categories developed, although
this section is not reported in this thesis. The findings are presented in tables, bar charts and narrative style with many original comments from respondents included. The analysis involved cross-case synthesis and pattern matching to the earlier one-to-one and explanatory case studies.

4.6 Summary of the Case Studies

It is believed that the exploratory case studies, the one-to-one case studies, the explanatory case studies and the MLSC case study are of an exemplary nature. These studies have been conducted in a rigorous manner, they are complete, and by interviewing non-dyslexic students alternative perspectives have been considered. They provide a significant contribution to knowledge in the fields of dyslexia and mathematics, and learning support (in the HE sector). It is also believed that the reports of these studies (see chapters V, VI, VII and X) have been written in an engaging manner.

4.7 Computer-Assisted Assessment and External Surveys

A small exploratory study to investigate whether dyslexic students are disadvantaged by CAA in mathematics, the effects of different media combinations on both dyslexic and non-dyslexic students and whether this form of testing gives a reliable indication of mathematical ability has been undertaken. Chapter VIII contains the procedure for, and findings from, this study.

Two external surveys have also been undertaken to determine the extent of the provision of mathematics support in UK HE institutions and also to investigate whether universities that provide mathematics support also offer one-to-one specific mathematical and statistical support for dyslexic students. Details of the procedures for these studies are included in Chapter IX.
The Exploratory Case Studies

The purpose of the six exploratory case studies, which were undertaken during the first year of this research, was to determine whether students who were diagnosed as dyslexic, after commencement of their undergraduate studies, were impeded in their learning and understanding of mathematics as a direct result of their dyslexia. This particular group of students was chosen because they would not have received any previous assistance to develop compensatory strategies. The findings from this research would determine whether subsequent explanatory multiple-case studies, to investigate whether there are particular areas of mathematics that prove problematic to dyslexic students and how these students might be disadvantaged by the delivery of material and its assessment, would be justifiable. These exploratory case studies would also provide training for the researcher in undertaking case study research.

The research design and associated documentation may be viewed in Appendix A. Each student was interviewed twice. The questions were posed to: determine educational background, reasons for dyslexia being suspected, whether visiting the MLSC had been helpful, level of support provided and problems encountered with mathematics. The narrative from these interviews gives valuable insight into the difficulties that dyslexia poses to students in HE and, in the main, details the general difficulties that were encountered and the reasons for the students suspecting that they may be dyslexic. Particular areas of mathematical difficulties are explored in the subsequent explanatory studies, which are detailed in Chapter VII. All the students participating in this research signed consent forms and verified that what has been written is correct. To protect the real identities of the participants, pseudonyms, which do not necessarily depict their true gender, have been used. However, the ratio of male: female participants has been maintained.

Each case study includes a narrative of the interviews, a report from a member of the MLSC and/or a member of the ELSU (when individual students were known to them). A précis of the EP report is included if available and if the student has consented that
access be given. This précis gives the student's IQ, particular strengths and weaknesses, recommended support and the percentile of the population that the student is in for each of four cluster groups. These cluster groups are verbal comprehension index (definition and understanding of words, and general knowledge), working memory (the storage and manipulation of information), perceptual organization (spotting missing details and finding the next symbol in a series, i.e., visual analytic skills) and processing speed (the ability to process visual information efficiently). There are particular implications for the study of mathematics, which are associated with working memory and processing speed; the two cluster groups where dyslexic students frequently obtain low scores. A low working memory index has a negative impact on the ability to perform lengthy or multi-stage mathematical operations. A low processing speed index affects the understanding of written instructions, which causes difficulty with lengthy and/ or predominantly text-based questions.

It is pertinent to mention that dyslexic students are part of a finite group of undergraduates. These students first need to be identified and then asked to participate. Not only are there students who do not wish to participate but, owing to the nature of dyslexia, those students who offer to participate may, due to short-term memory limitations, inadvertently fail to arrive at the specified time. The difficulty of obtaining a sufficient number of volunteers became apparent in the explanatory case studies (see Chapter VII).

The six students who participated in the exploratory studies came from several different departments at Loughborough University as shown in Table 3.

<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom</td>
<td>Manufacturing Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Robert</td>
<td>Electronic and Electrical Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Ryan</td>
<td>Systems Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Otto</td>
<td>Mathematics - MSc in Industrial Mathematical Modelling</td>
<td>One-year course</td>
</tr>
<tr>
<td>Keith</td>
<td>Ph.D in the Department of Chemical Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Mick</td>
<td>Ph.D in the Department of Chemical Engineering</td>
<td>Second year</td>
</tr>
</tbody>
</table>

Table 3: Students Participating in the Exploratory Case Studies
5.1 Case Study 1: Tom

Tom was interviewed after being diagnosed as dyslexic during the third year of his undergraduate studies. He had completed two years of a Mechanical Engineering course, but after experiencing problems had transferred to the second year of a degree programme in Manufacturing Engineering. Tom was approached by a member of the ELSU and agreed to participate in this research.

5.1.1 Interviews with Tom

Tom obtained nine GCSE’s: Geography and Physics at grade A*, Mathematics, Chemistry, English Language, French and German at grade A, English Literature and Biology at grade B. His only struggle at this stage of his education was with English and foreign languages. In both German and French he experienced difficulties with grammar. Fortunately he became proficient at speaking these languages and excelled in the oral component of the examination, which constituted 30% of the marks. Tom pointed out that his GCSE English and foreign language grades do not reflect the struggle he had with these subjects or the hours he spent learning spelling lists and says he was extremely lucky to obtain these results. Tom attended a Grammar School and explained that, “at both GCSE and GCE A Levels pupils were expected to obtain at least a Grade C”. It was at the commencement of his GCE A Levels that Tom first felt there was a disparity between his knowledge level and what he could actually write down and additionally noticed that he “found short questions easy to understand but long-winded questions difficult”.

Tom obtained four GCE A Levels: Physics at grade A, General Studies at grade A, Mathematics at grade B and Chemistry at grade E. He also obtained an AS Level in Philosophy at grade C. He described the physics syllabus, from his perspective, to be better than the chemistry syllabus. He found that physics questions were more easily answered in the examinations as “the syllabus focused on what needed to be said, just the subject details”. Tom described the chemistry syllabus as “vague, airy-fairy, and waffly” and continued “I was unclear in the examinations as to what was actually being asked”. At the beginning of the Chemistry GCE A Level course Tom expected a better result than a Grade E. However, as the course progressed, his actual result did not come
as a surprise to him. All the examinations for this subject were taken at the end of his GCE A Level study and questions such as “describe a process with equations” were a disaster for him as he experienced great difficulty in memorising equations. Tom felt that, “chemistry was presented in a crap way” and additionally felt angry saying “in my opinion these examinations were testing ability to recall a large amount of formulae and not really testing understanding of the subject”. Moreover, he feels that he would have done well in an oral examination.

Tom elaborated on the issue of how material is presented and gave a parallel of what is good for him by explaining that he had an old (1970’s reprint of a 1950’s publication) car workshop manual of his father’s which he described as “good”. What was written was only the essential information, i.e., only what needed to be said and additionally it was well illustrated. Tom could understand complicated procedures yet he often failed to answer simpler issues in a written examination.

Regarding his Mathematics GCE A Level, Tom described the first modular examination as “a disaster”, however, he does not attribute this to his being dyslexic, as most of his peer group obtained similarly poor results. Tom explained that once he had progressed further into the subject the material made sense and what was particularly useful to him was the availability of formulae sheets in the examinations.

He loved the discussions related to philosophy but hated the writing of essays even though he had a good understanding of the subject. Tom works and thinks intuitively, and is not a bookworm; he is extremely eloquent and fluid in his speech, loves talking and debating, has belonged to several debating societies and is extremely interested in theology. Tom describes himself as having “clearly defined opinions on many different topics”.

Tom’s interest in how things work started at a very young age. When he was about three years old he was taken to visit an Aunt and Uncle for Christmas. His Uncle had bought some small light bulbs, batteries and wires for him to play with. It was at this age that Tom first became interested in how things work. He is extremely creative and full of ideas and has been very annoyed on occasions to discover that what he thought was an
original idea had in fact already been patented. In addition to how things work, he is also interested in their design and is fascinated with the history of motor vehicles.

Tom commenced his studies at Loughborough University in October 2000, registered on a Mechanical Engineering Programme. His first year went well although he failed one mathematics module. Tom does not believe that failure of this module can be attributed to his dyslexia, but was his own error of judgement as he thought he was better at the subject than he was in reality.

Tom explained that he has never been able to revise effectively; he is better at learning “passively”, which he explained as “absorbing material over a period of time rather than consciously cramming”. He has a very good long-term memory but a very poor short-term memory and describes himself as being “very bad at remembering dates, names and faces”.

It was during his second year at University that “all hell broke loose and everything went pear shaped”. Tom was chairing a committee meeting one evening early in the first semester, at the end of which he collapsed and was taken to the Medical Centre. He was in the medical bay for four days suffering from a serious case of influenza from which he took about a month to fully recover. This was the point for Tom when things started to go wrong; he had to try and catch up and subsequently had a huge amount of reading to do. He found he could take a sheet of notes and read them but couldn’t remember them; he felt tired and physically ill after even a short session of work. Initially, Tom felt that feeling tired after reading the backlog of notes was due to his recent illness or maybe eyestrain. It was when this persisted that he realised something was wrong and knew that had he been at the lectures actually listening to the lecturer he would have retained much of the material. Tom tried to learn and catch up but just ended up in a mass of confusion, he started to panic and began to feel ill. At this time Tom was diagnosed as having depression. The second year, first semester examinations were disastrous for Tom, he failed four of the six modules. The two he passed were Mathematics (86%), which contained a lot of statistics he had already met at A Level and a design-based module, with a high practical content.
The commencement of the second semester in year two found Tom disillusioned and also angry about the lack of understanding from some members of staff in his department who suggested that the reason Tom was struggling was because he was not working hard enough. Tom attended the whole of the second semester and passed all but one module, however, he still felt that he wasn’t obtaining a good understanding of the material presented to him.

During his second year Tom was living in a shared house and noticed similarities between himself and his dyslexic housemate: “we both had messy writing, contempt for written learning, thought off the wall not the page and had similar exam failure techniques”. Tom explained what he meant by thinking off the wall not the page as having knowledge regarding a bizarre range of subjects, unusual ways of sorting things out, many new ideas, ideas oriented, seeing a problem and pulling in all the information he has absorbed and then finding a solution, although this finding of a solution has only been possible in the last couple of years as his knowledge base has expanded.

The time taken by Tom to learn a derivation or a proof meant that he had to neglect “about ten other areas of his mathematics module”. This has resulted in him usually entering an examination feeling extremely tired due to the tremendous effort he had expended on actually learning the material. Tom described his “exam failure technique” as often writing what he thought should be said, not what the examination paper had asked for, and during examinations he frequently became very tired and flustered.

While Tom was discussing aeroplanes and control systems with a dyslexic student who was at an advanced stage of a Mechanical Engineering Course it transpired that they both had a similar knowledge and love of aviation, and transport in general. It became apparent that “we could both see the effect that different issues had on reality but had difficulty in analysing the problem”. For example, Tom could understand car suspension dynamics and what was needed to ensure a car handled safely. The other student noticed that they both thought in the same way and suggested that Tom should be tested for dyslexia.

Tom’s degree programme included a year-out in industry and he had obtained a placement at Company X. The recruitment process involved a written test and a lengthy
interview, which Tom enjoyed. Fortuitously, the Company were compassionate regarding Tom's illness, subsequent depression and failure of his second year examinations. They had met Tom at interview, liked him and were not concerned about his poor examination results.

Tom felt that after his disastrous second year in Mechanical Engineering he did not want to retake his second year but would rather make a fresh start in Manufacturing Engineering and Management where he could commence the course at the second year stage. Therefore, at the time of his placement he was not classed as a student but considered to be on leave of absence. Fortunately Company X did not consider this to be a problem.

The depression straight after influenza, in the second year of his Mechanical Engineering Course, left Tom feeling extremely frustrated. He felt that his whole life was based on examinations and that there was no way to show his true capabilities. Once Tom commenced his placement his depression went almost as quickly as it arrived, he was given responsibility, was involved in designing things, became confident again and also added "I learned a lot". Consequently he was not unduly worried about returning to University but was apprehensive about starting a new course. As a result of his successful placement, Company X is sponsoring Tom for his two remaining years at University and they have offered him a job upon graduation.

When Tom returned to University after his placement, the first thing he did was visit the ELSU. A member of this department screened him for dyslexia; the test showed that Tom was likely to be dyslexic and in November 2003 an EP confirmed that he is dyslexic. The use of mind maps was suggested to Tom by a dyslexia support tutor but he has now created his own systems such as listing facts, flow charts and diagrams to help him recall and understand material. Tom is able to write slowly and accurately but if he has to write quickly his work becomes full of mistakes, which he is aware that he is making whilst he is writing. For example he mixes up the letters g and d and he makes spelling mistakes. Another problem Tom experiences is that, when a lecturer is talking, he can either listen and gain understanding or take notes – but not both at the same time. The style of lecture preferred by Tom is interactive but without stressful questions, and proceeding at a reasonable pace with physical demonstrations where
possible. He likes to be provided with notes for reference after the lecture but has
difficulty if they are used in conjunction with the lecture. Whilst he finds overhead
slides useful, he does experience difficulty in deciding what to actually write down. The
most problematic form of lecture delivery for Tom is when he needs to copy everything
from the blackboard, especially if the lecturer has unclear writing. Fortunately, Tom
now recognises that he is unable to listen and take notes. He has friends on the course
and has decided that at present his best course of action is to listen, which is where he
gains the greatest understanding then subsequently he photocopies the notes from a
friend thus enabling him to highlight any important formulae or definitions.

Tom loves the overall picture of things and prefers finding things out to being tested on
what he knows at the time of an examination. Tom also states that his time at Company
X, working in structural engineering, gave him confidence – if he couldn’t do
something, there was no big red cross. He just found someone who could do it and who
was willing to explain it to him. Tom and his Dad both think in similar ways and his
father now believes that he too might be dyslexic. Interestingly, Tom’s mother works in
Education as a geography teacher and teacher of students with behavioural problems
and feels highly embarrassed that she did not spot dyslexia in her own son when she
spots it in her classroom. Additionally, Tom’s mother believes that her sister (now
deceased), i.e., Tom’s Auntie, may have been dyslexic too. Both Tom’s parents know
that he is hardworking so did not believe that during the second year of his Mechanical
Engineering Course he had been wasting his time. Nevertheless, they were angry about
how he was treated; they felt that Tom had been placed on the scrap heap and was only
being tested on what he could recall. Now they are relieved, albeit a little embarrassed.

Tom was tested for dyslexia at school but it was not diagnosed. After visiting the DANS
at Loughborough University he felt relieved to know that there was a reason for his
difficulties but annoyed that school had not managed to determine that he was dyslexic.
He does not have any concerns regarding other students knowing that he is dyslexic.
However, he did express concern regarding the two month gap between being screened
for dyslexia and seeing the EP.

When asked whether he was enjoying his new course the answer was that he is enjoying
it better as the second year of his Mechanical Engineering Course was a “not to be
remembered experience”. Tom had used the MLSC on one or two occasions but his mathematics modules are not proving to be a problem now that he is no longer attempting to take down lecture notes.

Tom would like things valued in “a fundamental way” and feels that “too much emphasis is placed on book learning and regurgitating theorems”. He also feels that the establishment is only interested in examination results. Moreover, he believes that “it [the university] feels creativity is a bad thing and is trying to crush it out”. His preferred examination style would be a combination of coursework and a viva voce examination.

Tom enjoys computer games that require him to think, loves planning ahead and describes his chess playing as above average. Tom can read music and play the piano, however, he is not able to read the music and play with both hands at the same time.

Tom subsequently graduated with a Second Class Honours, Lower Division degree classification.

5.1.2 Report from the English Language Study Unit

Initially Tom appeared very anxious and was worried about commencing his course in Manufacturing Engineering and Management. He was concerned that history would repeat itself and he would encounter the same problems in his new course as those he had experienced in his Mechanical Engineering course. Tom felt isolated and knew something was wrong but not what it was. After talking to Tom it was arranged for him to return for a DAST, the result of which indicated that he might be dyslexic. Tom has short-term memory problems and is very anxious. After being diagnosed as dyslexic he attended workshops and discussions about skills and strategies, exam techniques and the use of mind maps. Coping strategies, and inappropriate strategies, for his short-term memory problems were also discussed. Tom had been spending lengthy periods of time trying to memorise material without knowing how to press ‘save’, whereas what he needed to do was to devise memory aids for himself. He was also worried about how he could be dyslexic and the school system fail to pick this up. Tom successfully
developed some coping strategies and following the June 2004 examinations, which went well for him, he was glowing.

5.1.3 Report from the Educational Psychologist

The EP's report revealed that Tom has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 117 which is greater than 87% of the general population in his age range. It describes Tom as having relative strengths in vocabulary development, verbal reasoning, general knowledge, reading comprehension, spatial problem solving, non-verbal matrix reasoning, basic number skills and mental arithmetic. Tom’s relative weaknesses are with working memory, processing speed and efficiency of retrieval of phonological information from long-term memory. The report grouped Tom’s results into four cluster groups (a grouping of scores which fall into the same category) showing what percentile of the population he was in for each cluster group and these are shown in Table 4.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>97th</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>47th</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>95th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>5th</td>
</tr>
</tbody>
</table>

Table 4: Tom's Cluster Group Scores from the Educational Psychologist

As can be seen, Tom's processing speed is extremely low and his working-memory index is also low when compared to his verbal comprehension and perceptual organisation scores. The learning of proofs and the recall of equations that Tom mentioned as proving difficult for him are in accord with his low working memory index. The difficulties he encountered with the A Level Chemistry syllabus and the reading of the lecture material that he had missed during his illness are in accord with his low processing speed index.
The report recommended that Tom be given individual specialist support on a weekly basis, technological support, 25% additional time for timed assessments, additional time to complete written coursework, a note taker in situations where there is a heavy writing requirement and additional loan times from the library. The purchase of personal copies of some books was also recommended.

5.2 Case Study 2: Robert

Robert was interviewed during the third year of his undergraduate studies and had been diagnosed as dyslexic during the second year of his Batchelor of Engineering (BEng) in Electronic and Electrical Engineering. Robert was approached by a member of the ELSU and agreed to participate in this research.

5.2.1 Interviews with Robert

At school Robert found science and mathematics easy whereas English and language-based subjects were difficult for him. He obtained seven GCSE's but failed to attain a pass in English. Robert commenced studying for his GCE A Levels with the need to re-sit his English GCSE examination; however, at this stage he began to experience difficulties. He obtained grade C in his GCSE English re-sit examination but after one year of the GCE A Level programme he decided to leave school.

Robert then obtained a 4-year apprenticeship with an electrical/electronic engineering company during which time he obtained Ordinary National Certificate (ONC) and Higher National Certificate (HNC) qualifications, which consisted mainly of science, mathematics and computing topics. Unfortunately, he was made redundant nine months before the end of his apprenticeship and it was at that time that he decided to enter university.

Robert found the first year of his course reasonably easy - with the exception of mathematics - and feels that the time he spent in industry was helpful to him. However, he did not have a GCE A Level in mathematics and, whilst the mathematics he had
studied to obtain his ONC and HNC qualifications was engineering-specific, it did not provide an adequate foundation for the mathematics he encountered at university. Robert struggled to keep up with the workload of the two mathematics modules, one in each semester, finding that he had large gaps in his mathematical knowledge and understanding compared to that of students who had studied the subject at A Level. Robert failed two modules in the second semester of his first year, namely, Mathematics and Circuit Theory. Nevertheless, he passed the first year of his degree programme.

It was during week seven or eight of his second year that Robert began to really struggle. While working in the MLSC he saw the newly-displayed checklists for dyslexia, he completed one, thought that he might be dyslexic and subsequently contacted the DANS. The DAST indicated that Robert was likely to be dyslexic and it was then arranged for him to see an EP. The diagnosis of dyslexia was confirmed in the second semester of Robert’s second year. Once Robert had been diagnosed as dyslexic he initially felt shy about it and also felt, “It was bad that the school system had failed to discover I was dyslexic and I had, in effect, had to diagnose myself”.

When lectures were delivered using an overhead projector (OHP) with bullet points on transparencies and the lecturer then expanded upon them Robert found note taking particularly difficult, discovering that he had “missed bits” and also experienced difficulty in deciding what to actually write down. However, when the whole lecture was delivered using a blackboard routine, Robert was not presented with any difficulties and was able to copy down exactly what was written by the lecturer.

In his second year, Robert failed what he describes as the “wordy examinations”; these were Engineering Mechanics, Introduction to Computer Networks, Principles of Energy and, additionally, Mathematics. For Robert to pass the second year of his degree programme it was required that he re-sit and pass two of the modules that he had failed. Robert chose to re-sit Principles of Energy and Mathematics, both of which he subsequently passed.

Prior to his dyslexia being diagnosed, Robert had sought help in the MLSC, however, it wasn’t the level of help he required and at this stage he just felt that he wasn’t working hard enough. Once he had been diagnosed as dyslexic Robert had one-to-one support
given by a member of the MLSC who specialises in providing mathematical help to dyslexic students. She explained the ‘where’/ ‘how’/ ‘why’ aspects of the mathematics module to him and Robert found this one-to-one mathematical assistance to be more helpful than general dyslexia support.

Robert has been given a recorder for lectures, which is proving to be useful. He doesn’t use it for the entirety of a lecture but uses it selectively, switching it on when he realises he will not be able to write down all the information being delivered, then after the lecture he is able to fill in the ‘missing bits’ in his lecture notes. Robert is unsure as to what else could be done to assist him but does appreciate the help he has received from some lecturers who have, prior to him receiving a recorder, helped him to fill in the missing parts of his lecture notes. Additionally, he has found that the extra time allowed for his examinations has been helpful.

Robert is aware that he will receive help from the ELSU with the written part of his final year project. This project accounts for three modules and constitutes a quarter of his final year mark. Robert commenced his project during the summer vacation preceding the final year of his degree programme and feels that it was being a mature student that enabled him to recognise the importance of this. He doesn’t feel that he will have a problem with his project; he has been able to spend adequate time with a dictionary checking what he has already written without being pressurised by time constraints.

Robert noticed that for wordy examinations he had to work harder than his non-dyslexic peers and realised that he needed to work out a strategy to enable him to cope. He now spends time rewriting his notes, making them as clear as he can, to enable him to revise from them more efficiently.

Robert has never learned to read music or play chess.

Robert failed the final year of his degree programme and did not return for the re-sit examinations.
5.2.2 Reports from the Mathematics Learning Support Centre

A member of staff in the MLSC knew Robert well as he had been seeking help in the Centre during the first year of his course. He failed one of his mathematics modules and additionally his other results were poor. She explained that he needed to read examples several times and experienced great difficulty in listening and then writing down what he had been told.

Another member of staff who provided Robert with one-to-one mathematical support reported that Robert had seen the checklist for dyslexia in the Centre and felt that these points applied to him. After being diagnosed as dyslexic, in the second year of his studies, it took Robert a little time to accept being dyslexic but he explained that talking to other dyslexic students had helped him. After being diagnosed as dyslexic, he benefited from one-to-one support and obtained over 50% in his second year mathematics re-sit examination and now appears happier and more confident. Robert has short-term memory difficulties and requires more time than his peers to absorb new material. He has spelling difficulties and needs to read material two or three times to absorb and understand it. His handwriting is reasonable when he concentrates and writes very slowly. Robert realises that he has great difficulties and finds the problems he has extremely frustrating.

5.2.3 Report from the Educational Psychologist

The EP report revealed that Robert had an IQ (WAIS-III) of 111, which is greater than 77% of the general population in his age range. It describes Robert as having relative strengths in verbal comprehension and perceptual organisation and relative weaknesses with working-memory, processing speed, sequential ability and phonological processing. The report grouped Robert’s results into four cluster groups, see Table 5, showing what percentile of the population he was in for each cluster group.
Table 5: Robert’s Cluster Group Scores from the Educational Psychologist

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
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<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>82&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>70&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>73&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>32&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
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The problems with wordy examinations that were described by Robert and his need to read material several times to absorb and understand it (mentioned by a member of the MLSC) are in accord with his low processing speed index.

The report recommended that Robert be given an individual programme of support, technological support, special examination arrangements of 25% extra time, extra time for coursework and a tape recorder.

5.3 Case Study 3: Ryan

Ryan was interviewed during the final year of his 4-year Masters degree in Systems Engineering. He was diagnosed as dyslexic during the third year of his studies. Ryan was approached by a member of the ELSU and agreed to participate in this research.

5.3.1 Interviews with Ryan

At school Ryan realised that, compared to his peer group, he was slow at reading and had to work hard to keep up. He recognised that he had a tendency to make silly mistakes, but was not aware that he was dyslexic. He consistently achieved good marks and obtained nine GCSE’s, four A*’s, four A’s, one B and one C. His lowest grades were a B in English Language and a C in French.

Ryan then commenced his GCE A Level studies and obtained three grade ‘A’ passes in Chemistry, Mathematics and Physics. In General Studies he obtained grade E and added
"I realised that an information gathering format was not right for me". This subject entailed lengthy perusal of newspaper articles regarding current affairs and then required him to digest the information and put forward an argument to explain it. These are all areas that Ryan finds difficult as he frequently loses his place when reading, which results in him either missing out part of the text or reading sections twice.

During the first year of his degree he found the module on ergonomics particularly difficult and the coursework extremely time consuming. Ryan explained that he has a need to understand why things happen and why things work. Furthermore, whilst he may have knowledge and understanding of a subject in his head, it takes him a long time to put it into words on a page and it also entails a lot of redrafting. Ryan stressed that he worked extremely hard and achieved an average of over 70% in both the first and second years of his course.

In addition to the four years of study at University, his course also requires students to spend a year in industry between the second and third years of their study. This ‘year-out’ was spent at Company Y and Ryan received good reports from his placement. He was working in a business environment and was able to summarise the reports he needed to make by using either ‘PowerPoint’ or bullet point presentations of his work as opposed to writing lengthy detailed reports.

It was in the third year of his degree that Ryan began to feel frustrated. One of the course requirements was an assessed group project. He found that he was not able to explain and communicate his ideas to the other three members of his group; they thought he was being stupid and laughed at paragraphs he had written. It was while he was in the MLSC that Ryan saw the leaflets explaining dyslexia and thought that many of the checkpoints listed applied to him. Ryan discussed his situation, explaining not only his problems but also pointing out that he was achieving high marks, with the dyslexia-dedicated member of staff in the MLSC who then arranged an appointment for him at the ELSU. It was about two weeks later that Ryan attended this appointment and was provisionally screened for dyslexia. Ryan was believed to be dyslexic and after a further two weeks was seen by an EP. The final report was not available prior to his second semester third year examinations, nevertheless, he was given a 25% extra time allowance in these examinations. Ryan said this extra time would have been particularly
useful in the ergonomics and materials modules examinations taken in his second year and a module in his third year, which entailed essay writing. For mathematics and engineering-based modules he has not had any difficulties completing a paper in the given time. Ryan again obtained an average of over 70% in his third year. The EP report confirmed that Ryan is dyslexic and he is entitled to an additional 25% time allowance in his examinations.

Ryan has found mind mapping, which was recommended to him by the DANS, to be helpful and he has been supplied with 'e-mind' software. After a lecture Ryan translates his pages of notes into coloured mind-mapping diagrams, which he finds easier to work and revise from. For each module he has approximately 11 of these diagrams and prefers to hand draw each of them himself, adding, "I absorb the material more easily if I draw them myself". A module 'Software Project Management' consisted of 25-60 slides per session being presented by the lecturer. Ryan found that once he had drawn himself a mind-map, not only was it useful for revision but it also helped him to understand relationships. In general, the Systems Dynamics-related modules tended to use a diagrammatic representation, which Ryan finds user friendly.

The fourth and final year of Ryan's study entails a final year project; Ryan has chosen to do a Human Sciences dissertation related to systems, which is mainly creative work and feels that he will benefit from a member of the ELSU looking at his final report.

One of the skills required by Systems Engineers is an ability to see the whole picture, which Ryan is able to do. The company who funds Loughborough University to run this course and provides students with placements and bursaries would, according to Ryan, like a screening test to see if candidates would make good Systems Engineers as the attrition rate on this course is very high. There were 96 students in Ryan's first year, but in his final year there are less than 50. As dyslexic people are often able to see the whole picture, Ryan suggested that research into the characteristic traits of dyslexics might prove useful.

Once Ryan had discovered that he was dyslexic he was not concerned about friends on his course knowing of his dyslexia. Ryan's mother had always thought that he could be dyslexic and he has a sister who is dyslexic. Ryan has found that he works best if he is
first given a five-minute talk on a topic; then with this overall picture of a subject he is able to go away and read or research any necessary material. He finds unstructured web sites extremely difficult to use, preferring ones that have links from a central point. If Ryan misses a lecture he finds it hard to understand the subject from the notes alone. He also experienced difficulty in Computer Graphics where the lecturer supplied printed notes and then talked through the material. Ryan’s preferred lecture style is a bullet point presentation with comprehensive notes being available afterwards, but not both being used together. Ryan does not require a note-taker, as he is able to write quickly enough to keep pace with the material being delivered, but does experience difficulties if he has to decide what to write down. Ryan describes his writing as “sometimes messy and sometimes neat” and explains that this difference is not always related to the speed at which he is writing. He describes his spelling and sentence structure as “horrible”.

Ryan can play chess, read music and plays both the guitar and the trombone.

Ryan subsequently graduated with a Master of Engineering (MEng) First Class Honours degree classification.

5.3.2 Report from the English Language Study Unit

Initially Ryan was worried about being dyslexic and writing his final year project. Additionally, he was concerned that he was wasting people’s time, as his average mark was indicative of him obtaining a First Class Honours degree. Ryan experienced difficulties with concentration, note taking and writing, was frequently unable to remember what he had read and was unable to work if there was any background noise. He had orientation problems, which resulted in him ‘getting lost’. After being diagnosed as dyslexic Ryan wanted to talk and needed to know what he could do to help himself and how being dyslexic would affect him. He was keen to learn compensatory tactics; he attended workshops, met other students and developed coping strategies. He wanted to know everything. He is now happier and more confident. Ryan had always chosen modules that suited his strengths and realised that the compulsory final year project was going to be difficult for him. Although he had chosen a creative subject for his project, a written report was still obligatory. Help with his written English was provided.
5.3.3 Report from the Educational Psychologist

The EP's report revealed that Ryan had an IQ (WAIS-III) greater than 70% of the general population in his age range. It described Ryan as having relative strengths in vocabulary, alertness to visual detail, spatial problem solving and non-verbal matrix reasoning and relative weaknesses with working memory, auditory analysis skills and efficiency of retrieval of phonological information from long-term memory. The report grouped Ryan's results into four cluster groups, see Table 6, showing what percentile of the population he was in for each cluster group.

The report recommended that Ryan be awarded extra time for examinations, given tutorial support and technological support.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
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<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>68th</td>
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<tr>
<td>Working Memory Index</td>
<td>37th</td>
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<tr>
<td>Perceptual Organization Index</td>
<td>86th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>58th</td>
</tr>
</tbody>
</table>

Table 6: Ryan's Cluster Group Scores from the Educational Psychologist

The difficulties with concentration that were highlighted by a member of the ELSU are in accord with Ryan's low working memory index. His low processing speed index is the reason for his difficulties with reading and understanding what he has read.

5.4 Case Study 4: Otto

Otto was interviewed whilst undertaking a Master of Science degree (MSc) in Industrial Mathematical Modelling. He was approached directly by the author of this thesis who was aware that he had been diagnosed as dyslexic during the final year of reading for his Batchelor of Science (BSc) in Mathematics.
5.4.1 Interviews with Otto

Otto was tested for dyslexia in Year 8 of his school education and the result showed that he was a marginal dyslexic. Subsequently, Otto was placed in an additional needs group for English. Otto continued to receive this support up to the GCSE level of his education. Otto obtained eight GCSE's: Mathematics at grade A, Design, Graphics and Sport at grade B, Double Science, Statistics and Geography at grade C, English Literature, English Language and French at Grade D.

Otto continued his education by re-sitting English Language GCSE and studying for three subjects at GCE A Level. He obtained a grade C in his English Language GCSE re-sit. At GCE A Level Otto experienced difficulty with mathematics when it was necessary for him to extract the relevant data from that which was supplied but, despite these difficulties, he obtained a grade A. The Chemistry GCE A Level involved essay style questions, which Otto was concerned about. He describes his English skills as "abysmal" and feels that this was the area of the examination where he lost a lot of marks; his final result was a grade C. In Design Technology he obtained a grade D.

Otto entered HE to read mathematics and graduated with a Second Class Honours Lower Division classification. In the first year of his degree programme Otto passed all his modules but found that he was slow at writing down lecture material. He experienced difficulty when mathematics were presented orally but was competent working with formulae. The same problems continued during the second year of Otto’s degree where he also encountered difficulties with lengthy or multi-stage mathematical operations, but he again passed all his modules.

The final year of his course required the undertaking of a project worth three modules, which accounted for one quarter of the year’s marks. Motion in Magnetic Fields was Otto’s choice of project, however, whilst working on this project he started to worry. It seemed to him, to be “an insurmountable job” to actually write up his dissertation. It was this difficulty that prompted him to be formally tested for dyslexia. Initially he made an appointment in the MLSC to see a dyslexia-dedicated member of staff. This staff member suspected dyslexia and referred him to the DANS where he was screened for dyslexia. The results indicated that Otto was dyslexic, however, he had to wait over
half a semester to see an EP. In the second semester of his final year, whilst still awaiting his assessment, Otto encountered problems in another module, Special Relativity. The examination for this module did not allow the use of calculators and one of the questions entailed the writing of an essay.

Prior to his assessment, Otto received some help from the dyslexia-dedicated member of staff in the MLSC. Although she was unable to help him with the mathematics at this level, she assisted him with his written work. Otto was diagnosed with dyslexia and allowed 25% extra time in the final examination session of his degree programme and allowed access to computing facilities. Otto found both the use of a calculator and the extra time to be particularly helpful in Special Relativity. He feels that the extra time would also have been helpful in some previous modules, which required explanations of methods used or descriptions of situations. However, unless an examination required paragraphs of writing he did not actually require this extra time allowance. Otto failed one module in his final year but states that this was due to his lack of preparation for the examination not his dyslexia.

Otto was also offered a note taker but prefers to make his own notes as he absorbs the material more easily when he has written it down himself. When Otto writes quickly he has a problem with spelling and sometimes uses incorrect symbols or writes them back to front but when writing slowly he describes his presentation as “not too bad”. Otto’s preferred style of lecture delivery is when the lecturer explains the topic as he writes it on the blackboard. Otto prefers to see the whole picture as this enables him to understand and apply the methods encountered. He is not very good at learning an isolated topic. Otto did not have any concerns regarding lecturers or members of his peer group knowing that he was dyslexic.

His mother who is a teacher and his father who is an engineer were not surprised to learn that Otto had finally been diagnosed as dyslexic. They were aware of his difficulties and arranged additional English lessons for him when he was at junior school. Otto’s mother had to re-sit her GCE O Level in English and his father, who excelled at mathematics, had taken his GCE O Level examinations a year early yet needed to re-sit English twice to obtain a pass. Otto has two brothers, one of whom also
had additional English lessons at junior school but passed GCSE in English at his first attempt. Otto describes his other brother as “a genius”.

Otto at the time of the interview was working towards an MSc in Industrial Mathematical Modelling and feels it would be of great help to him to have his own computer. DANS are aware of this need and Otto is to be provided with an iMac loaded with software that has the facility to ‘speak back’, a scanner and a printer. Otto has also been given a voice recorder, which he uses during descriptive sections of lectures. Otto had passed all the first semester MSc examinations.

Otto plays chess, reads music and plays both the piano and guitar. When playing the piano he is better with his right hand than his left hand, but does not know if this can be attributed to dyslexia or insufficient practice. He feels that he has mathematical strengths and musical ability.

Otto subsequently obtained his MSc.

5.4.2 Report from the Mathematics Learning Support Centre

Otto received one-to-one support, for one hour per week, during the second semester of the final year of his BSc in Mathematics. He has problems reading textbooks, writing essays or essay style answers and with spelling. He takes longer than his peers to read and make notes, and finds making non-mathematical notes very difficult. Additionally, he has difficulty understanding what questions are actually asking him to do. Although Otto has performed well so far, he currently has several modules requiring a greater degree of language-based skills. Regarding his current modules, he feels that he is disadvantaged by the difficulties he has with reading, writing and spelling. Otto would benefit from continued support during the remainder of his time at Loughborough University.
5.4.3 Report from the Educational Psychologist

The EP report revealed that Otto has an IQ on the WAIS-III greater than 77% of the general population in his age range. It described Otto as having relative strengths in spatial problem solving, non-verbal reasoning and alertness to visual detail and relative weaknesses in processing speed, working-memory and speed of retrieval of phonological information from long-term memory. The report grouped Otto’s results into four cluster groups, see Table 7, showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
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<tbody>
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<tr>
<td>Working Memory Index</td>
<td>42nd</td>
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<tr>
<td>Perceptual Organization Index</td>
<td>99th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>14th</td>
</tr>
</tbody>
</table>

Table 7: Otto’s Cluster Group Scores from the Educational Psychologist

The difficulties Otto experienced with lengthy mathematical operations are in accord with his low working memory index. It is not surprising that he found the writing of his final year project to be “an insurmountable job” considering his very low processing speed index.

The report recommended Otto be given support to develop his literacy skills, technology support and a 25% extra time allowance in examinations.

5.5 Case Study 5: Keith

Keith was interviewed during the final year of his Doctor of Philosophy (Ph.D) research. He was approached by a member of the ELSU and agreed to participate in this research.
5.5.1 Interviews with Keith

Keith was interviewed in 2004, prior to submitting his Ph.D thesis to the Department of Chemical Engineering. Keith stated, "I had all the signs of dyslexia, I was a slow reader, misread lines and experienced problems with the text appearing to move on the page but didn’t realise that I was dyslexic". It was not until the final year of his Ph.D research that Keith was diagnosed as dyslexic.

Keith was born in Iraq and entered primary school when he was six years old although education in Iraq generally commences at seven years of age. The educational system in Iraq required six years at primary school followed by elementary school from the age of 13. At primary school he did learn some English, but mainly vocabulary rather than sentence structure and grammar. Keith commenced elementary school when he was 12 years old but he was deported to Country B before completing his first year of study at this level.

Keith was in a refugee camp in Country B where it was required that children study and then take an examination to determine which year of schooling they should enter. Keith managed to obtain results that placed him at the level of having done one year of elementary study even though he had not completed this in Iraq. English was taught in Country B, but only at a basic level and this only repeated the material that Keith had already encountered.

After four years in Country B, Keith moved to Country C, where he studied for examinations, which he described as being roughly equivalent to the former GCE O Level in England. He then commenced study for a BSc in Agricultural Engineering. He did not complete this degree as he moved from Country C to the UK when he was 22 years old.

Once in the UK he wanted to obtain qualifications that would enable him to enter university. Keith estimated that taking the route of studying English first and then taking GCE A Levels would take him 4 years. Instead he decided to take a Business and Technology Education Council (BTEC) First Diploma in Applied Science, feeling that as he already knew the subject well it would be a way of learning English. He judged
that he would be familiar with or recognise the technical words and would then learn English by reading, and completing homework assignments. He felt that this was a more appropriate and quicker approach than doing an English Language course. He entered a London College and completed a BTEC in Science followed by a 1-year Access to Science and Technology Course. With these qualifications he was able to satisfy university entry requirements in the UK.

After only two years in England he applied and was accepted to read for a BSc in Food Technology at an English university. This was a 4-year course, which required a 'year out' in industry. For the duration of his undergraduate studies Keith undertook paid employment in order to support himself. At the time of entering University to read for his degree he had already decided that he wanted to continue studying beyond undergraduate level and work towards a Ph.D. He did not waiver from this decision even though, during his undergraduate studies, academic staff advised him against this.

Keith recalled that, as an undergraduate, whenever he encountered any report writing or essay style work he became extremely stressed and used to think "Am I so stupid that I can't understand what is required". He described the problem he had after missing a lecture - he borrowed the lecture notes from a girl on his course who always produced neat and well structured notes - but he just couldn't understand them so he then got notes from another student, but this did not help either. He realised that if he missed a lecture he could not grasp the material and would not be able to even attempt an examination question that related to the topic. He explained, "The lecture was the key thing for me - as long as I'd attended the lecture I could recall and understand the material. I took notes as spoken by the lecturer, although I often found out afterwards that I'd missed bits out".

Regarding mathematics, he is emphatic that if he has been shown how to solve something he won't remember it, however, if he works through a problem himself he will remember it. He recalls that in Country C he was competent at mathematics, having no problems understanding topics such as differentiation and integration. However, he does experience problems with text appearing to move on the page and this frequently results in him making errors in questions involving matrices. He did have some problems with the mathematics he encountered during the first year of his
undergraduate studies, saying, "I wasn't following what was being said". He explained that the material was so elementary that he couldn't believe it was part of an undergraduate course and the problem arose because he was trying to make it more difficult. The mathematics that he encountered during the second year of his undergraduate studies were harder yet he didn't encounter any problems with these. He describes himself as being much better at dealing with abstract mathematics than numerical work where he is prone to making transcription and computational mistakes. He also emphasised that he needs to know, "Why we do it and what it is used for".

Whilst at university his tutor suggested that he go for English Support in the Medical Centre. Keith was puzzled by this and did not follow up the suggestion. His tutor did not mention dyslexia. Keith hated language courses and did not realise that this was dyslexic help being offered to him. His own strategy for learning English had been to take a BTEC in Science.

Keith hates text-based material but is good at mathematics, and interpreting and understanding graphically-presented material. He needs to read things more than once to understand the concept and has developed the strategy of just reading for key words. He describes himself as creative and good at idea generating but hates group work and other people seeing his written work. He found his undergraduate dissertation to be an area of great difficulty, but at this stage he attributed his difficulties to working in a language that was not his native tongue. He acknowledges that he was fortunate that his girlfriend was willing to read and correct the English in his dissertation for him. He graduated with a Second Class Honours, Upper Division classification.

He came to Loughborough in 2000 to undertake a Ph.D in the Department of Chemical Engineering and, after four years, he is almost ready to submit his thesis. It was whilst having a discussion with a dyslexic friend during the third year of his Ph.D that it occurred to Keith that he might be dyslexic. Subsequently he made an appointment with a member of the ELSU and was screened for dyslexia. The DAST produced a positive result, indicating that he might be dyslexic. In the fourth year of his research an EP confirmed that Keith is dyslexic. Unfortunately, as Keith was in the final year of his postgraduate research, it was too late for him to apply for the DSA, which would have
enabled him to have his own computing equipment. However, the DANS gave an old computer plus software to Keith and he stresses that this has been a great help.

After being diagnosed as dyslexic he felt frustrated, it was the final year of his Ph.D, which was taking him four years to complete; he needed a quick solution but recognised that there were not any quick solutions. At the time of being diagnosed as dyslexic it was too late for him to start learning new coping strategies, as he had to finish writing his thesis. Keith has developed his own strategy, which is to read once, read again and then remember the concept. He also added, “One of my brothers is dyslexic and is actually scared to write a letter. Even with dyslexia in my own family I didn’t recognise that I was dyslexic and just wish that I had paid more attention to the evidence that was staring me in the face”.

Regarding his Ph.D, he produced a first year report of around 30,000 words (the requirement was for 10,000 words). His supervisor corrected it three times for him and told him that he was repeating himself. When producing his second year report he actively tried to avoid this repetition but received comments from his supervisor that he needed to be more precise, however; his second year report only needed to be corrected once. Keith also added “my supervisor cut loads out of my Ph.D thesis”.

Now that Keith is aware that he is dyslexic he would like to help other dyslexic people. He proposes that, once he has found employment, he would like to spend some time learning web design and then set up an Arabic web page explaining dyslexia. There is currently little recognition of dyslexia in Arab-speaking countries and he hopes that this would help to raise awareness of the condition.

Keith was subsequently awarded a Ph.D.

5.5.2 Report from the English Language Study Unit

Initially Keith was worried about a report he needed to submit in the next one to two months. At this time he had not commenced writing it and was unable to get the words from his head onto the page, as he first needed to be able to visualise something in order
for him to understand it. It was of great concern as to how Keith was going to cope with the writing and completion of his thesis. Keith also mentioned that the funding body for his Ph.D had agreed to extend the time allowed for his research as he had encountered some interesting results. Time was spent showing Keith how to use ‘tree diagrams’, bullet points and mind mapping, thereby breaking down, what was for him, a monumental task, into smaller more manageable sections. Keith also required help with organisation and planning.

5.5.3 Report from the Educational Psychologist

The EP’s report revealed that Keith had an IQ on the (WAIS-III) greater than 63% of the general population in his age range and it was noted that English is not Keith’s native tongue. It described Keith as having relative strengths in reasoning skills (very superior), non-verbal reasoning (superior), spatial problem solving, working memory, long-term memory, general knowledge and basic number skills. Keith’s relative weaknesses are with processing speed, grapho-motor fluency (handwriting), alertness to visual detail, short-term auditory sequential memory, efficiency of retrieval of information from long-term memory and vocabulary development (which again may be related to English not being his first language). The report grouped Keith’s results into four cluster groups, see Table 8, showing what percentile of the population he was in for each cluster group.

The report recommended Keith be given specialist dyslexia support, additional tutorial support from his academic department, additional time of 25% in timed assessments and examinations, additional time to complete written coursework, specific help with English and technological support.

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<tr>
<th>Cluster Group</th>
<th>Percentile</th>
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<tbody>
<tr>
<td>Verbal Comprehension Index</td>
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<td>Perceptual Organization Index</td>
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</tr>
<tr>
<td>Processing Speed Index</td>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
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</table>

Table 8: Keith’s Cluster Group Scores from the Educational Psychologist
As can be seen, Keith's processing speed index is extremely low which is the reason for his difficulties with reading, understanding what he has read, and writing.

5.6 Case Study 6: Mick

Mick is currently in the second year of his Ph.D in the Department of Chemical Engineering at Loughborough University. It was as a result of his friendship with Keith, that he became aware of the exploratory studies that were being undertaken and contacted the author of this thesis with an offer to participate. Mick was diagnosed as dyslexic during his undergraduate studies at an English university.

5.6.1 Interviews with Mick

Mick was born in Sudan and lived there until he was 14 years of age, at which time he had studied English for two years but only for one hour per week. His elder brother was in England as an exchange medical student and his mother, who had been doing a Ph.D correspondence course at Birmingham University, came to England to do her final year write-up and brought Mick with her.

Once in England, Mick completed the Cambridge First Certificate in English and also obtained six grade C GCSE’s. His elder brother remained in England and Mick also remained to continue his education and studied for four GCE A Levels. He obtained a grade B in Arabic. He had been predicted grade B passes in the other three subjects but obtained: Chemistry at grade C, Mathematics at grade D and Physics at grade E. At this stage he just thought that they had been "bad exams”.

Mick’s tutor had suggested that he apply for a place at university and as he had been resident in and studying in England for over three years he was entitled to a grant. He obtained a place at an English university to read for a degree in Chemical and Environmental Engineering. He failed the first year of his course, obtaining an average of 13%, and was devastated; all of his exams took place at the end of the academic year and he was not allowed a dictionary. Mick attributed his failure to English not being his
first language. He explained that he was unable to take down adequate notes in lectures as the presentation of material was too fast for him and he was often unable to make sense out of what he had written afterwards. At this stage his tutor told him that he was not HE material.

He then worked for approximately one year as a handyman/labourer. Mick came from a professional family and at this point they intervened and said that he must do something with his life. He applied and was accepted, at a different English University, to read for a degree in Mechanical and Environmental Engineering. He recalls that he tried very hard and managed to obtain a first year average mark of 56%. His tutors complained about his coursework and mentioned the English Support Unit to him. Mick recalls problems such as “writing waist management instead of waste management”. He says that he was extremely fortunate, as his personal tutor’s daughter had recently been diagnosed as dyslexic at school and his tutor thought that Mick might be dyslexic too. His tutor said to him “You have more than English Language problems”.

Mick did not know what dyslexia was. Fortunately his tutor intervened and obtained money from the hardship fund at the student union to pay for Mick to undertake a dyslexia test at a local assessment centre. Mick was tested on 27th April 1999 and subsequently told that he was dyslexic. As a result of this, he was awarded extra time in examinations, the use of an English/Arabic dictionary, extra-time to complete coursework and additional loan time for library books. It was also recommended that tutors should provide him with notes. He describes the lecturers that he encountered at his second UK university as falling into two categories, “The younger lecturers were most often in touch with dyslexia but many of the older lecturers didn’t believe that dyslexia existed and said that I was lazy”.

Mick did not recall having any difficulty understanding the mathematics modules at his second university. However, he did encounter problems when working with matrices and had to use a ruler to enable him to correctly align the rows and columns of numbers. He was also unable to remember most of the formulae he needed and had to derive almost all of them from first principles whenever he required them. He also recalled, “I had a bit of trouble using statistical tables, and found thermodynamics tables particularly difficult”. The main problems he encountered were in the energy/
environment modules. These required the writing of essays and to help to structure his work he used bullet points and tree diagrams. His final results were a high 2:1 in Mechanical Engineering and a low 2:2 in Environmental Engineering. He then undertook a viva hoping to obtain a 2:1 overall classification but obtained 57%. He graduated with a Second Class Honours, Lower Division classification.

After graduation Mick spent nine months doing temporary work before obtaining a position with Company Z as an Environmental Engineer. This company allowed £500 per annum to be spent on employee training/development. Mick used this funding to complete a MSc., at a different English university, in Environmental Management. During his employment at this company he communicated with his French (non English-speaking) colleague by using tree diagrams and bullet points. However, he did not feel that his promotion prospects were good, as he did not speak French and decided to terminate his employment and re-enter HE.

In January 2003 Mick came to Loughborough University to undertake a Ph.D in Chemical Engineering. At the end of his first year it was required that he submit a 10,000-word report. When Mick presented his supervisor with 120 pages he was asked “Do you expect me to read all this?” However, his supervisor did read it and also corrected Mick’s mistakes. At this time Mick was having support with his written work from the ELSU.

Mick had visited the DANS and given a staff member a copy of his report from the EP confirming that he was dyslexic. This member of staff contacted Mick’s LEA in an attempt to obtain a grant for a computer for him but was unable to do so as Mick had only been a British subject for two years. However, the DANS were able to lend a computer to Mick for the duration of the undergraduate summer vacations.

Mick is funding his own Ph.D and works at one of the University Halls of Residence as a sub-warden; this gives him a rent-free flat plus the provision of food and Internet connection. He has also obtained a £20,000 loan from his bank, £10,000 of which he has spent on tuition fees. He pointed out, “This debt is on top of the student loans, which I incurred as an undergraduate”.

- 116 -
During his MSc he had used, and further developed, his system of tree diagrams. He is again using them to help him with his Ph.D, where they have been particularly helpful to him with the writing of his literature review, which he found extremely difficult. Mick has two brothers, neither of whom are dyslexic. His final comment was, "My mates find the way I undertake procedures to be bizarre".

5.7 Triangulation of Data

There are points from each of the interviews that are corroborated by the reports from members of the ELSU and the MLSC, which suggests that the students have honestly reported their individual situations and experiences and are aware of their difficulties. For example, Tom mentioned during one interview that he was annoyed that his dyslexia had not been detected at school and this is also in the report from a member of the ELSU. Robert described himself as initially feeling shy about being dyslexic and the member of staff in the MLSC reported that it took him time to accept his diagnosis.

There is also evidence of correlation between the EP reports and what was determined by the interviews. For example, Tom’s verbal comprehension index is in the 97th percentile and he was found to be highly articulate. He has also chaired committee meetings and has belonged to several debating societies.

5.8 Summary of the Findings

The cluster group scores for those students who participated in the exploratory case studies, and whose EP reports were viewed have been collated and are shown in Table 9. From this table it can be seen that compared to their Verbal Comprehension Index and their Perceptual Organisation Index all the students obtained a lower score for their Working Memory Index and their Processing Speed Index. As mentioned at the beginning of this chapter, low scores in these areas impacts negatively on the ability to undertake multi-stage mathematical operations and to process detailed written instructions.

- 117 -
<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
<th>Tom</th>
<th>Robert</th>
<th>Ryan</th>
<th>Otto</th>
<th>Keith</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>97&lt;sup&gt;th&lt;/sup&gt;</td>
<td>82&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>68&lt;sup&gt;th&lt;/sup&gt;</td>
<td>63&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>79&lt;sup&gt;th&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>47&lt;sup&gt;th&lt;/sup&gt;</td>
<td>30&lt;sup&gt;th&lt;/sup&gt;</td>
<td>37&lt;sup&gt;th&lt;/sup&gt;</td>
<td>42&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>53&lt;sup&gt;rd&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>95&lt;sup&gt;th&lt;/sup&gt;</td>
<td>73&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>86&lt;sup&gt;th&lt;/sup&gt;</td>
<td>99&lt;sup&gt;th&lt;/sup&gt;</td>
<td>68&lt;sup&gt;th&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>32&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>58&lt;sup&gt;th&lt;/sup&gt;</td>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Students in the Exploratory Studies – Collated Cluster Group Scores

Using cross-case synthesis six different areas of difficulty that were encountered by the participants in these exploratory case studies have been determined:

- Note-taking
- Understanding material if a lecture is not attended
- Recall of formulae and/or theorems
- Visual disturbance
- Reading and recalling
- Essay writing

The areas of difficulty and the students who experienced them are shown in Table 10.

<table>
<thead>
<tr>
<th>Name</th>
<th>Note-taking</th>
<th>Understanding material if a lecture is not attended</th>
<th>Recall of formulae and/or theorems</th>
<th>Visual disturbance</th>
<th>Reading and recalling</th>
<th>Essay writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Robert</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryan</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Otto</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keith</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mick</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Difficulties Experienced by Students in the Exploratory Case Studies
Additionally, five of the students (Tom, Robert, Ryan, Otto and Keith) pointed out that they need to see the whole picture, i.e., Ryan specifically mentioned the need to understand why things happen and why things work. This area will be re-visited in Chapters VI and VII.

The difficulties encountered with note taking have particular repercussions in mathematics. In a more language-based subject, difficulties with note taking, resulting in transcription errors, reversal of letters, spelling mistakes and grammatical errors, do not, generally, render notes to be incomprehensible. For example words such as *was* spelled as *saw* will be easily identified from the context of the material. However, in mathematics it is imperative that the material is copied exactly. For example, a missing minus sign, an incorrect power or suffix may drastically alter the context of the material and the method that will be used to solve it, for example, quadratic equations. Transcription errors are also likely to make coherent following of a worked example difficult, if not impossible, depending on where the errors occur, and indeed, how many of them are made.

Three of the students experienced difficulty in understanding material if they had missed a lecture. Mathematics delivered in lectures contains more detail than that which is to be found in mathematical texts and additionally it is delivered with an accompanying explanation. It is easy to envisage that for all students the missing of a lecture might prove to be problematic but for dyslexic students it appears that the accompanying explanation is the key to understanding. Tom mentioned that it is best for him to listen to a lecturer and obtain the notes from a friend afterwards. Obtaining the lecture notes from another student, without having listened to the explanation, does not result in an understanding of the material. Moreover, attempting to process the information from a textbook, where diagrams may be separated from the explanation, and examples may refer to numbered equation several pages removed from what is being read, is likely to make comprehension fraught with difficulty for the dyslexic student. The problem may be alleviated by the provision of recording devices and note takers, although the usefulness of recording devices appears to be subject dependent. This area is explored further in Chapters VI and VII.
Three of the students had difficulty with the recall of formulae and/or theorems. Many of the formulae that are needed are in the formulae book which is available in examination halls; nevertheless, there are some formulae that students are expected to recall. Mick explained that he had to derive almost all formulae from first principles. In an examination setting it is easy to appreciate, that for those who need to derive formulae, this is going to place them at a disadvantage in terms of the time taken. Regarding theorems, it is desirable that students understand the proof. Nevertheless, for many undergraduates this is not the case and proofs are often learned line by line. On the other hand, it is often through this rote learning that understanding develops. Students who are unable to commit to memory many lines of working are therefore at a disadvantage when faced with questions of this nature.

For the three students who experience visual disturbance, this is likely to cause difficulties when using statistical tables and working with rows and columns of figures as encountered in work with matrices and systems of equations. In such work, it is likely that numbers will be incorrectly aligned and/or transcription errors occur. This is discussed in more detail in Chapter VI and further evidence of these difficulties being encountered, due to visual disturbance, is included in Chapter VII.

The subject of mathematics does not instantly bring to mind the writing of essays and copious reading requirements. However, occasions do arise; for example, modules such as ‘The History of Mathematics’ require in-depth reading and the writing of essays, other modules frequently require definitions or a physical description of what is occurring to be given in examinations. Statistics questions often include a lengthy descriptive text, from which it is necessary to extract the relevant information. Otto related the difficulty he was faced with when one of his modules - Special Relativity - required an essay to be written under examination conditions. It is apparent that mathematics modules that require reading and recall of what has been read, followed by essay writing, place heavy demands on dyslexic students (see Chapters II and III) and this is likely to put them at a disadvantage when compared to non-dyslexic students.
5.9 Conclusion

All the students in these exploratory case studies experienced difficulties with note taking, with reading and recalling material, and with essay writing. Additionally, five of the students also experienced difficulty with some of the remaining categories. The conclusion reached is that there is evidence to suggest that students who are diagnosed as dyslexic after commencement of their undergraduate studies are likely to experience problems with mathematics that can be directly related to their dyslexia. Moreover, the difficulties that are encountered have the potential to disadvantage dyslexic students.

The questions relating to ability to play chess and read music were initially posed as it was suspected that poor short-term memory would have a detrimental effect on the ability to play chess and visual difficulties would make reading music difficult. However, it became apparent that the answers to these questions were, to a certain extent, related to the social and educational background of the participants and would not prove useful in the research being undertaken. These questions were not asked in the final two exploratory case studies; nevertheless it is considered that this is an issue, in its own right, that may be worthy of future research.

These exploratory multiple-case studies have found evidence to suggest that dyslexic students are disadvantaged in their learning and understanding of mathematics. The findings from this study and the number of dyslexic engineering students studying at Loughborough University (see Chapter III, section 3.7.2) have justified the continuation of the one-to-one support studies (see Chapter VI) and the undertaking of explanatory multiple-case studies. The explanatory studies (see Chapter VII) investigate whether there are any particular areas of mathematics that prove problematic to dyslexic students and how these students might be disadvantaged by the delivery of material and its assessment.
The author of this thesis provided one-to-one mathematical support to three undergraduate engineers. Another student was also supported but his difficulties were found to be of a non-mathematical nature and he is not reported herein. The first student, referred to as Patrick, was both dyslexic and dyspraxic (motor control difficulties); he received support with four mathematics modules during the first two years of his Civil Engineering degree programme. The second student, referred to as Peter, was dyslexic; he received support with one mathematics module during the second year of his Mechanical Engineering degree programme. The third student, referred to as Russ, was dyslexic and also had mental health difficulties; he received support with his mathematics during two semesters of his engineering degree programme. Each student received support for one hour per week during term time. From a research perspective this contact proved to be invaluable, as it enabled the researcher to witness the areas in which these students were experiencing difficulties and to then develop strategies to help overcome them. Two in-depth case studies were undertaken with Patrick and Peter and are detailed in sections 6.1 and 6.2 respectively. As in the exploratory case studies (Chapter V), triangulation of data is provided by reports from members of staff who know these students and a précis of the EP reports. In addition, each case study includes details of the difficulties that were encountered by the students, as observed during the support sessions, and the mechanisms that were introduced to help these students. A case study was not undertaken with Russ, as it was believed that this might have been stressful for him, however, section 6.3 gives a brief account of working with him. Triangulation of data, the findings from these studies and concluding remarks are given in sections 6.4 - 6.6. The findings from these one-to-one support case studies along with those from the exploratory studies (Chapter V) contributed to the design of the explanatory multiple case studies (see Chapter VII).

The research questions that were posed are:

1. How does dyslexia impede the learning and understanding of mathematics for engineering students in HE?
2. How can dyslexic students be helped to overcome their mathematical difficulties?

From these questions, seven hypotheses were formulated:

Hypothesis 1: Dyslexic students experience difficulty with note taking.
Hypothesis 2: Dyslexic students experience difficulties with multi-stage mathematical operations.
Hypothesis 3: Some dyslexic students experience visual problems, which results in difficulties being encountered when working with rows and columns of figures or equations.
Hypothesis 4: Dyslexic students experience difficulties with lengthy descriptive text.
Hypothesis 5: Dyslexic students experience difficulties with the application of notation and recall of formulae.
Hypothesis 6: Drop-in support at the MLSC is inadequate for dyslexic students.
Hypothesis 7: Dyslexic students may be helped to overcome their mathematical difficulties.

It is the acceptance or rebuttal of each hypothesis that will determine the answers to the research questions.

6.1 Case Study 1: Patrick

The author of this thesis supported Patrick with his mathematics modules during the academic years 2003/2004 and 2004/2005. He is reading for a MEng in Civil Engineering and received support with four modules, one in each semester, during the first two years of his course. He was diagnosed as being dyslexic and dyspraxic shortly after commencing his undergraduate studies. It was through supporting him that some of the questions for the explanatory case studies and the subsequent one-to-one case study with Peter (see section 6.2.1) were developed, namely:

- Do you use any of the software you have received through the DSA (if this has been provided)?
- Are there any areas of mathematics that you understand but frequently obtain the wrong answer for?
• Do the mathematics tutorials address any difficulties that you encounter?
• Have you encountered any forms of testing that proved particularly difficult?
• Have you been given coloured overlays and if so do you use them?

A further question was also included:

• Is the drop-in support at the MLSC adequate for your needs?

This question was added as a result of a comment made by Robert (Chapter V) who mentioned that the MLSC did not provide the level of support that he required and the comment that was made by Patrick (see Chapter VI, section 6.1.1).

The following section includes information that was recorded during two discussions with Patrick, undertaken during the first few weeks of his one-to-one support, which he has verified as being correct.

6.1.1 Discussions with Patrick

Patrick explained, “At primary school I was labelled as a lazy pupil with good potential”. During the final year of his primary education he spent Friday afternoons with the headmaster doing additional English and mathematics. During his later education Patrick recalled that the situation deteriorated saying, “At secondary school I became labelled as disruptive”. He sat ten GCSE subjects, achieving four grade B’s (History, PE and Double Science), four grade C’s (Mathematics, Double English and Graphics), grade D (French) and grade E (Information Technology). He was allowed to continue onto the A Level programme but was not predicted to pass any of the examinations, being told again that he was lazy.

He decided to leave secondary school and enrolled at a local college to study for his A Levels, however, by this time he hated and feared mathematics and did not want to continue with the subject. His chosen A Level subjects were: Politics, History and Law. On his first day at college he changed his mind and instead opted to do Chemistry, Physics and Biology. Subsequently, he then changed from Biology to Physical Education (PE). Patrick’s description of this period of study was, “It went terrible, I had
no motivation and was repeatedly told that I was lazy”. He then stopped attending classes because he couldn’t do the work. Patrick estimates that his attendance rate was only about 30% and at the end of his first year at college he failed all the modules he had taken. The college threatened to expel him, however, he managed to pass his re-sit examinations and eventually obtained Chemistry at grade D, Physics at grade E, and PE at grade C. Patrick described himself as being “fed up” at this time, adding, “No-one in education had ever been good to me”.

After college he spent the summer thinking, “Bollocks to everything”. Patrick then went to a local Technical College and enrolled on an electrician’s course. As one of the few people on the course with A Levels he was selected for an apprenticeship. He was employed by an electrical company and continued at college on a day release programme. He worked for this company for one year but was bored with the repetitive work and finally decided, “This ain’t the life for me”.

He decided to read for a degree in Pharmaceutical Chemistry and applied to several universities. He was offered places at two universities, one university rejected him and another university offered him a place on their foundation year. Patrick explained that he decided to accept the offer of a foundation year rather than accept offers from what he described as, “Mickey Mouse” universities.

However, he only stayed on the foundation programme for two months. He found the area to be extremely rough and explained that there were fights actually taking place in lecture theatres. He feels that, “The course was funded to help inner city kids”. He also added, “There did not appear to be any departmental responsibility”; he needed a discharge of course certificate but was unable to find a tutor to sign it.

He then returned home and said, “I sulked and pondered my future and eventually decided to go back to college and attempt to obtain decent A Level grades”. After working on a building site for a few months he entered college in January to take A Levels in Chemistry, Physics and Mathematics, deciding he could not avoid mathematics for the rest of his life. He said that he worked really hard, describing this effort as, “I worked my bollocks off”. Unfortunately, in May someone grabbed his girlfriend and Patrick said, “I saw red and attacked the lad, I head butted and kick boxed
him". Patrick had been kickboxing since he was 15 and inflicted substantial injuries to this person. A security camera had recorded the incident and Patrick was subsequently expelled. At this time Patrick had been attaining top marks in his classes for chemistry and physics but was struggling with mathematics. He continued with the subjects by teaching himself and sat the examinations. He achieved AS levels in all three subjects, Chemistry at grade A, Physics at grade A and Mathematics at grade C. He was unable to find another college in the area that was using the same examination board and felt like giving up. He explained, "I just couldn't face starting again". He wrote a letter to the college apologising for his behaviour and was allowed to return. He continued with his A Levels but was struggling with mathematics; however, he found a private mathematics tutor and paid £12.00 per hour for additional help. During this period at college Patrick also ran a clinic for first year students who were struggling with physics and chemistry.

For his A Levels he was predicted to obtain Chemistry at grade A, Physics at grade A and Mathematics at grade B but obtained B, B, D, respectively. Patrick had applied to six universities including Loughborough. He was offered places by all of these except one (Patrick decided not to attend the interview as it was too far to travel). In the end, Patrick selected only Loughborough, which he described as, "A real university without either an old boys club atmosphere or boring image". His conditional offer from Loughborough University was for grades B, B, C. As soon as Patrick obtained his results he started to panic as he'd failed to obtain the requisite grade C in mathematics. He phoned the programme tutor who said that he would be accepted but asked Patrick not to let him down in mathematics.

At this stage, Patrick said that his friends were having bets that he would be home by Christmas.

Patrick commenced reading for his MEng degree at Loughborough University in October 2003, aged 21. During the first year of his course, in week four or five, he had to undertake a CAA in mathematics. He expected to obtain a good mark, as he understood the material he was being tested on, but was devastated with his result of 15%. He spoke to a member of the MLSC and explained what had happened. At this point he was ready to leave the university and felt that he would never pass anything.
The member of staff suggested dyslexia and Paul went to the ELSU and the DANS and, as a result of the DAST, it was considered that he was likely to be dyslexic. He received support from this time although his appointment with the EP did not take place until the following March. He was subsequently diagnosed as being dyslexic and dyspraxic.

Patrick described himself as being forgetful and having difficulty with anything that requires a high level of organisation. Regarding mathematics, he explained that he encounters the greatest difficulty with isolated topics unless he can see how they relate to the areas of mathematics that he has already encountered, and also with multi-stage operations where he forgets what he needs to compute next. During his second time at college he started to draw himself mind maps for each subject. He uses an A3 sheet for each mind map and then displays them on his bedroom wall. He explained, "It is the creating of these maps that helps me to understand the topic and see the topic as a whole. They really help me at revision time too. I get really nervous in exams but often I can visualise my mind maps and that helps". Figures 8, 9 and 10 show copies of mind maps drawn by Patrick. These mind maps do contain some errors and it is unlikely that they would be helpful to another student as mind maps are a highly individualistic means of revision (see Chapter VII).

Patrick has up-to-date lecture notes for all his modules that he has taken himself. He describes the speed of lectures to be very quick and says that he is frequently still copying down material from the blackboard after everyone else has finished. He has used the MLSC frequently but added "I feel that without the one-to-one support I would be practically living in it [the MLSC] in order to obtain enough help as it's difficult to have enough time with the lecturer on duty".

A member of the ELSU suggested that Patrick use a blue overlay but he did not obtain one and has no intention of doing so. He experiences some visual disturbance and explained that he uses two wooden rulers when reading information from statistical tables.
Figure 8: Patrick's Mind Map for Advanced Algebra

**Remainder & Factor Theorems**

- The Remainder Theorem: When a polynomial is divided by $(x-a)$, the remainder is $f(a)$.
- Most problems require a polynomial to factor and remove. Find first the base equation using something like Euclid's A.B.C.

**Advanced Algebra**

- $(1+x)^n = 1 + nx + \frac{n(n-1)x^2}{2!} + \ldots$
  (Do not need to learn, in formula book)
- Must be in the form $(1+x)^n$
  $\therefore (9+x)^n = 4^n(1+\frac{x}{3})^n$
- $x < 1$

**Partial Fractions**

- If the degree of the denominator exceeds that of the numerator, $\frac{5x+1}{(x-2)(x+3)}$ may be expressed as $\frac{A}{x-2} + \frac{B}{x+3}$.
- The ideal way to find values of constants $(A, B, etc.)$
  $x^2 + 5x + 6 = A(x+3)^2 + C$....

- If there is a non-repeated factor in the denominator then $\frac{2(x^2-x+1)}{(x-3)(x+2)}$ will be expressed as $\frac{A}{x-3} + \frac{B}{x+2}$.

**Binomial Expansion**

- Infinite series
- Example
- A fraction is improper when the degree of the numerator is equal to or larger than the degree of the denominator.
  $\frac{2x^3+8x+7}{x^2+5x+6}$
  Divide the top by bottom using long division.
  $\frac{2}{x^2+5x+6} - \frac{2x^3+8x+7}{x^2+5x+6}$
  Now this may be expressed as a partial fraction.
Figure 9: Patrick's Mind Map for Probability

- Mutually exclusive events
  - Addition rule
  - $P(AUB) = P(A) + P(B) - P(ANB)$
  - $P(ANB) = 0$

- Independent events
  - $P(ANB) = P(A) \times P(B)$

- Event
  - Set of possible outcomes

- Conditional probability
  - Multiplication rule
  - $P(ANB) = P(A|B) \times P(B)$

- Probability of $A \cup B$ and $A \cap B$
Figure 10: Patrick's Mind Map for Differentiation
6.1.2 Report from the Author of this Thesis

Patrick is a diligent and extremely hard-working student. He arrived for his support sessions with evidence of work he had completed or attempted. For any questions he was unable to answer, it was evident that he had attempted to do so as he was able to refer to the section of his lecture notes where he was having difficulty in understanding the material. He displayed evidence of working memory limitations when undertaking multi-stage mathematical operations and he also experienced some visual disturbance when reading from statistical tables or working with rows and columns of figures, details of which are given in section 6.1.4. Patrick failed to attend only one support session; this was when the time of his meeting had been changed. On two other occasions he sent an email, several days before his support session, to explain that due to coursework deadlines he had not had time to attempt any of his mathematics tutorial questions and asked if his support session could be rescheduled. Patrick’s mathematical ability was more than adequate for his course but his working memory limitations, the visual disturbance he experiences and his tendency to rush through calculations (which resulted in him making careless mistakes) all conspired against him. He passed all his mathematics modules but the marks he obtained were lower than those anticipated from the evidence of his work in support sessions.

6.1.3 Report from the Educational Psychologist

The EP’s report showed that Patrick has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 113, which is above average. It describes Patrick as having relative strengths in visual working memory, verbal and non-verbal reasoning, verbal expressive skills and level of knowledge. His relative weaknesses are in processing and organisation of auditory information (auditory working memory). The report grouped Patrick’s results into four cluster groups (see Table 11) showing what percentile of the population he was in for each cluster group.
<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>86&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>55&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>82&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>87&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 11: Patrick's Cluster Group Scores from the Educational Psychologist

As can be seen, Patrick's working memory index is low compared to the other three areas. As witnessed by the author of this thesis, and referred to by Patrick, he experienced difficulties with multi-stage mathematical operations. Patrick also described himself as being forgetful and this was confirmed by him forgetting to attend a support session for which the time had been changed, i.e., the session was at a different time to that which he had written on his timetable. These shortcomings are linked to his low working memory index.

The report recommended that Patrick be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, and computing equipment with appropriate software.

6.1.4 Working with Patrick

Patrick was initially quite anxious about his mathematics module and terrified about the next CAA that he would shortly be undertaking. At this time it was observed that he had a tendency to rush through his work, which resulted not only in many transcription errors but also key words in questions being overlooked. In the practice CAA tests, that he attempted, this was particularly apparent. Patrick often failed to read the question with enough care and tended to overlook instructions such as give your answer correct to 2 decimal places. This was the primary reason for him failing to obtain correct answers in this form of testing and prompted the question 'Have you encountered any forms of testing that proved particularly difficult?' being asked to those participating in the subsequent explanatory case studies (see Chapter VII). At this stage of working with Patrick it was not considered that the speed at which he worked was related to his
dyslexia. However, this tendency to rush through calculations, especially those involving multi-stage operations, was also observed with Peter (see section 6.2.4) and Russ (see section 6.3) who both received support after Patrick. When Peter (and at a later date Patrick) were asked why they worked at such a fast pace it was found that this was related to their dyslexia, in particular, to their processing speed and working memory limitations; they were concerned that they would forget all the steps that needed to be undertaken.

Patrick experienced particular difficulty, initially not recognised by him, when working with matrices and solving systems of equations (especially when using Gaussian elimination). This became apparent at one support session when Patrick said, “I don’t need any help with this tutorial sheet, its just solving equations and I know what I’m doing”. However, when Patrick was asked to undertake some of the questions his answers were found, in the main, to be incorrect. This led to the question, ‘Are there any areas of mathematics that you understand but frequently obtain the wrong answer for?’ being included in the questions that were asked in the explanatory case studies (see Chapter VII). The reason for Patrick’s difficulty in this area was that he experienced some visual disturbance when reading. It had been suggested by a member of the ELSU that he use a blue overlay but Patrick chose not to do so. It was Patrick’s decision not to use an overlay that gave rise to the question, ‘Have you been given coloured overlays and if so do you use them?’ being posed to the students participating in the explanatory case studies.

With matrix operations Patrick also encountered difficulty with finding the inverse of a matrix using the method:

$$A^{-1} = \frac{1}{\det A} \text{adj} A$$

He became confused between the two operations of finding the determinant and finding the adjoint, experiencing difficulty with linking the task to the operation. It was only after the provision of a template, and a lot of practising by Patrick that he was able to complete this method successfully.
Squared paper was also provided to help him to align rows and columns of working. This squared paper is freely available from the World Wide Web (http://incompetech.com/beta/plainGraphPaper/) where it is possible to design your own graph/ squared paper, allowing both the colour of the lines and the colour of the paper onto which you print to be chosen. This enables the design to be ‘tailor made’ to suit individual requirements and preferences, thereby reducing the glare that is experienced by some students.

It was clear that the squared paper helped him with his matrix work, considerably reducing the number of errors that he made. It is believed that the squared paper played a dual rôle; it not only enabled Patrick to correctly align rows and columns of figures but also the transcribing of each number/ letter into a small box resulted in him writing more slowly, thereby reducing the number of transcription errors that he made. During the second year of his course, when work with rows and columns of figures was again encountered, Patrick was asked if he had any squared paper with him. His response was, “I don’t need it any more”. After questioning Patrick about why he no longer needed the squared paper the answer was twofold. It transpired that as a result of using the paper, he realised that he needed to write more slowly and he also recognised the importance of writing neatly (which he was able to do when working more slowly) but, as the equations he was working with had grown in size it was necessary for him to use smaller boxes. With smaller boxes he then encountered even more visual disturbance due to the lines being so close together. Nevertheless, Patrick agreed that during his early work with matrices the squared paper had been beneficial.

Patrick also experienced difficulty with early vector work whereby he was unable to move from a 2-d representation to a 3-d conceptualisation. This was overcome by using a basic 3-d model comprised of an empty carton and rulers to depict the vectors.

As mentioned earlier, Patrick often missed key words when reading questions. Not only did this occur in CAA but also when using paper-based material. This was particularly apparent in statistics questions where he frequently missed important information. For example, in questions of the form, ‘Find the probability that at any given time at least one component is working’, he often found the probability of exactly one component
working. Other mistakes involved failing to observe important words such as 'independent'.

It was during the first year of his course that Patrick explained why he believed his one-to-one support was necessary. He found there was insufficient time in tutorials to address some of the difficulties he encountered. For topics that he did not understand, he needed greater time, on a one-to-one basis, than was available. This was instrumental to the question 'Do the mathematics tutorials address any difficulties that you encounter?' being included in the interview questions that were asked during the explanatory case studies (see Chapter VII). He frequently used the MLSC and found it to be helpful if the issue was finding out where he had gone wrong in a calculation but if he needed more in-depth help with a particular topic then there was inadequate time available with the lecturer on duty to address his needs. Patrick explained that he needed to understand how isolated topics related to each other and to the mathematics he had already encountered. He needed to be able to link topics together and draw a mind map for each of them. He did not use the provided mind mapping software, preferring to draw the mind maps himself, as did the majority of the dyslexic students who used mind maps and participated in the explanatory case studies (see Chapter VII). It was this lack of use of the supplied software that prompted another question, 'Do you use any of the software you have received through the DSA (if this has been provided)?' being asked in the explanatory studies.

Patrick, in earlier discussions, had mentioned that he found the speed of delivery in lectures to be too fast for him. It became apparent that this was indeed the case. At one support session he was having difficulty in understanding, from his lecture notes, how a particular line of a calculus calculation had been arrived at. Calculus was not a topic that Patrick had been seen to encounter any difficulty with. On looking at his lecture notes it was suggested to him that he had either missed out a line of the calculation or missed the explanation given by the lecturer. Through comparison of Patrick's notes with those of his friend (who was waiting for him to finish his support session) it was found that Patrick had missed the explanation that was given. Patrick's friend had written this explanation in the margin of his page. What was also ascertained was that Patrick had failed to number some of the equations. It had been intended, in the explanatory studies, to include the question, 'Do you have an up-to-date and accurate set of notes for your
mathematics modules?' This question, as a result of working with Patrick, was changed to, 'Do you have an up-to-date set of notes for your mathematics modules'. It was realised that the students being interviewed would not be in a position to ascertain whether or not their notes were accurate. Once Patrick received a recording device this difficulty with note taking was minimised; he recorded lectures or parts of lectures, listened to the recording during the evening and then annotated his notes accordingly.

Patrick also found new mathematical notation confusing, for example, when faced with the notation for Cramer’s rule to find a solution of the system of equations:

\[ Ax = b, \]

where:

\[ x_i = \frac{\det(A_i(b))}{\det(A)}, \]

he was unsure as how to proceed. A colour coded model answer was provided. This clearly demonstrated that the column vector \( b \) replaced the column containing the coefficient of the variable that was to be determined.

The emphasis in engineering mathematics modules tends to be related to application rather than rigorous proof. One question that was frequently asked by Patrick during his mathematics modules was, “But why does it work?” For example, Patrick wanted to know why the ratio test and L’Hospital’s rule worked; he wanted proof of these methods. When rigorous proofs were supplied to Patrick, although he was unable, in most instances, to follow the line of reasoning from start to finish, he was able to accept it. As his modules progressed he was content to be told that a proof did indeed exist.

Patrick was able to link the mathematics he encountered during the first year of his course to the mathematics he had met in his GCE A Level, as the university material was building upon that which he had already encountered. For example: complex roots as opposed to real roots, using Gaussian elimination to solve systems of equations rather than solving a pair of simultaneous equations and calculus of a more advanced nature. However, during the second year of his course when faced with eigenvalues he found
himself somewhat at a loss as to what to link this operation to. He explained that he needed to see a more global picture, to understand what they were used for and why they worked. The problem appears to have arisen as Patrick was expecting all the mathematics he studied to be directly linked to that which he had already met, as indeed was the case during the first year of his course.

It was not until after Patrick had completed his mathematics modules and was undertaking his work placement that a satisfactory explanation was envisaged. During a tutorial session, being conducted by the author of this thesis, a dyslexic student posed a similar question about eigenvalues. It was explained to him that topics in mathematics required the use of building blocks (basic arithmetic) and tools (for example, solving systems of equations, calculus and eigenvalues). Both building blocks and tools would then be used in particular topics. The student enjoyed gardening and the explanation was then related to maintaining a garden. In this scenario the building blocks consisted of knowing the difference between plants and weeds, the time of year to sow seeds etc., and the tools consisted of the garden equipment and knowing how and where to use them. A particular topic might be, for example, the vegetable patch, which requires building blocks and the correct choice of tools. The student concerned was satisfied with the explanation and it is believed that it would have been particularly beneficial to Patrick in helping him to visualise relationships and would also have assisted him in the construction of his mind maps.

The main difficulty that Patrick encountered during his second year was with multi-stage operations, which is commensurate with his low working memory index. Amongst these operations, Fourier series proved to be the most challenging. His understanding of what a Fourier series was, the sketching of a particular series if a sufficient number of terms were taken, and the distinction between odd and even functions was excellent. He did not encounter any difficulties with performing the necessary integration. The problem for Patrick was to remember all the different calculations that needed to be undertaken.

The formula for Fourier series:
\[ FS = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(nx) + b_n \sin(nx), \]

is given in the formulae booklet, which is available in examinations. Interestingly, Patrick did not experience any real difficulty in memorising this formula although to do so was not necessary. The suggestion was made to him that \( a \) comes before \( b \) in the alphabet and likewise \( \cos \) comes before \( \sin \) alphabetically, this suggestion enabled him to link together the '\( a \)' with the \( \cos \) term and the '\( b \)' with the \( \sin \) term. Patrick did not feel confident about entering a mathematics examination without having previously learned all the formulae he was likely to require. He explained that whilst he had concerns about his ability to recall formulae he did not worry unduly as he knew that the formulae booklet would be available. However, he did not like using it in examinations as this interrupted his concentration and was likely to result in him losing track of the process he was undertaking.

After several sessions working on Fourier series Patrick announced, “I’ve got Fourier series pretty well sewn-up now”. This statement was somewhat alarming as Patrick had, at this stage, failed to complete a question without being prompted. The problems experienced by Patrick were related to his working memory limitations and resulted in him not completing all the necessary computational steps.

In most Fourier series questions, what was required was for Patrick to compute some or all of the terms, \( a_0 \), \( a_n \) and \( b_n \) (depending on whether the function was odd, even or neither), using the formulae:

\[ a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \cos(nx) \, dx \]

\[ b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin(nx) \, dx , \]

and then write out the required number of terms in the Fourier series.
Patrick frequently omitted one or more of the required operations, which resulted in him failing to answer the question correctly. For example, he sometimes failed to calculate the 'a_0' term and in cases where it was necessary to distinguish between the n-odd and n-even terms he often forgot to do so. If, at the end of the question, he remembered to write out the Fourier series then he discovered his omissions. He was then able to perform the necessary calculations and thereby complete the question. However, what recurrently happened was that he failed to write out the Fourier series and thus had, in effect, only completed approximately half of the required computation. The help given to Patrick did not involve colour coding or a diagrammatic representation, which often proves to be beneficial to dyslexic students. It was apparent that if Patrick could remember to write out the completed Fourier series he would then become aware of his omissions. Patrick was repeatedly told, “The most important thing is to write out the Fourier series at the end of the question”. He was also encouraged to underline the words ‘Fourier series’ in the question and to write ‘find the Fourier series’ at the side of the question. Interestingly, Patrick sometimes underlined the words in the question or annotated the question but, what he eventually did before commencing a new question was to talk aloud the sentence, “The most important thing is to write out the Fourier series”, whereby, he discovered any omissions he had made.

Regarding the results for n-odd and n-even, Patrick always needed to sketch graphs of the sine and cosine functions before proceeding. He was unable to recall which graphical representation was the sine function and which was the cosine function. He never referred to the formulae booklet, again mentioning that this distracted him. He always spent time plotting a few points to determine the graphs. Figure 11 shows the approach that was successfully taken to help Patrick recall these functions.

For many topics the author of this thesis constructed a detailed handwritten solution to a particular question. Patrick used this as a template for future questions and then reduced the ‘model answer’ to a few key points. An example of this is the solution to a tutorial sheet question using Lagrange multipliers that was provided for Patrick (see Figure 12).
During the two years of supporting Patrick there was one question that he repeatedly asked, namely, “Can I start drawing my mind map now?”. He needed to know if all the material that would be encountered in a particular topic had been covered. This was particularly apparent with topics such as integration and Fourier series. It would have been beneficial to Patrick if an overview of what was to be covered had been discussed during the first lecture on a particular topic. For example, if Patrick had known that Fourier series would contain different approaches for odd functions, even functions, $2\pi$-periodic functions, non-$2\pi$-periodic functions etc., he could have started to build up his mind map at an early stage and then, when all the material had been covered, draw his detailed colour-coded version.

After supporting Patrick during his first mathematics module not only did it become apparent where his difficulties lay but Patrick also realised that his difficulties were recognised and anticipated. This was made clear when, at the commencement of each of his subsequent modules, Patrick posed the question, “What topics am I going to find difficult in this module?”

Figure 11: A Memory Aid for Sine and Cosine functions
Q: A rectangular block with edges $x, y, z$ is cut from a sphere of radius $b$ so that the volume has a maximum value. Find $x, y, z$ and show that the maximum value is $\frac{3b^3}{3\sqrt{3}}$.

**Model Answer**

1. Extract all possible information from the question.

   - Volume of rectangular block:
     $$V = xyz$$

   - Equation of a sphere: $x^2 + y^2 + z^2 = b^2$
     
     Note: Here radius $(r) = b$

2. For our rectangular block to have been cut from the sphere, it is necessary for the $x, y, z$ sides of the rectangle to have the following properties:
   
   - $x < 2b$ 
   - $y < 2b$ 
   - $z < 2b$ 

   Rearranging gives:
   
   - $\frac{x}{2} < b$ 
   - $\frac{y}{2} < b$ 
   - $\frac{z}{2} < b$

3. Our equation for the sphere is now:

   $$(\frac{x}{2})^2 + (\frac{y}{2})^2 + (\frac{z}{2})^2 < b^2$$

   and:

   $$\frac{x^2}{4} + \frac{y^2}{4} + \frac{z^2}{4} < b^2$$

4. Write out and label:

   - The objective function
   - The constraint
   - The augmented function

   **Objective fn:** $xyz$ (volume of rectangular block)
   **Constraint:** $\lambda (\frac{x^2}{4} + \frac{y^2}{4} + \frac{z^2}{4} - b^2) = 0$
   **Augmented fn:** $xyz + \lambda \left( \frac{x^2}{4} + \frac{y^2}{4} + \frac{z^2}{4} - b^2 \right)$
3) Find \( f_x, f_y, f_z \) of the augmented function and then set to zero:

\[
\begin{align*}
    f_x &= yz + 2\frac{zx}{4} = 0 \quad (i) \\
    f_y &= xz + 2\frac{xy}{4} = 0 \quad (ii) \\
    f_z &= xy + 2\frac{xz}{4} = 0 \quad (iii)
\end{align*}
\]

taking each equation \((i), (ii), (iii)\) in turn:

for \((i)\) \[ yz + 2\frac{zx}{4} = 0 \]
\[ yz = -2\frac{zx}{2} \]
(multiply both sides by \(x\)) to give \[ xyz = -2x^2 \]

for \((ii)\) \[ xz + 2\frac{xy}{4} = 0 \]
\[ xz = -2\frac{xy}{2} \]
(these time multiply both sides by \(y\)) to give \[ xyz = -2y^2 \]

for \((iii)\) \[ xy + 2\frac{xz}{4} = 0 \]
\[ xy = -2\frac{xz}{2} \]

\[ \text{we need} \]
\[ \text{[XYZ] on the LHS is the volume of our rectangle.} \]
\[ \text{so rearrange multiply both sides by \(z\) to give} \]
\[ xyz = -2z^2 \]

\[ \text{We now have:} \]
\[ xyz = -2x^2 \]
\[ xyz = -2y^2 \]
\[ xyz = -2z^2 \]

\[ \text{Therefore:} \]
\[ -2x^2 = -2y^2 = -2z^2 \]

\[ \text{This tells us that} \quad x = y = z \]

4) Now use the constraint

\[ \lambda \left( \frac{x^2}{4} + \frac{y^2}{4} + \frac{z^2}{4} - b^2 \right) = 0 \]

but we know that \( x = y = z \)
Considerable time was spent with Patrick in determining the best use of his extra time in examinations. He was encouraged to spend half of his extra time doing the following:

i) Carefully reading the question paper to determine which questions he would answer.

ii) Underlining key words.

iii) Annotating the paper with reminders such as, ‘write out the Fourier series’.

It was also suggested to him that the remainder of his extra time should be spent in checking through his working. After Patrick had completed some past papers his confidence grew and he did stop rushing headlong into answering a question before he had read it thoroughly. Additionally, as a result of completing past examination papers
within the time that he was allowed, he gained confidence and worked through questions more slowly.

It transpired that the suggestions for the best use of his extra time and the past examination papers that he had completed had been beneficial to Patrick. He reported that, whilst he was still prone to panicking in examinations, he felt more confident as he realised that he did have enough time available, he was aware that annotating the questions helped to prevent him losing track of what he needed to compute, and additionally, he had positive memories of previous examination papers.

Overall, it was found that Patrick was helped by regularly re-visiting methods of computation, explaining methods in more than one way, providing colour-coded templates and model answers, providing simple 3-d models and ensuring that the working environment was un-pressurised and comfortable. Above all, patience is required when working with dyslexic students. Repetition of material resulted in processes being transferred to long-term memory and the comfortable working environment enabled Patrick to ask, what he referred to as, “Dumb questions”, without any qualms.

Patrick was happy to discuss the difficulties he encountered, was interested in the research for this thesis and also willing for staff to know that he was both dyslexic and dyspraxic. He travelled to Leicester to listen to a presentation on dyslexia in HE given by the author of this thesis at a DDIG event in March 2004. He also mentioned that he had, during a university vacation, visited his former school to tell pupils of the mathematical support that is available at Loughborough University. Regarding his mathematics modules Patrick mentioned that whilst he found some aspects of mathematics difficult and sometimes required more detail than was provided in lectures he realised that there was a lot of material to be delivered. He was grateful not only for the one-to-one support that he was receiving but also for the open door of his lecturer and the MLSC.

Patrick successfully completed his year in industry and has returned to Loughborough University to continue reading for his MEng degree.
6.2 Case Study 2: Peter

Peter was supported in one mathematics module during the second semester of the academic year 2005/2006. At this time Peter was in his second year of reading for a degree in Mechanical Engineering. He had originally entered Loughborough University to read for a degree in Mathematics, however, during the first year of this course he changed his mind and subsequently changed courses.

The following section includes information that was recorded during one interview with Peter, which he has verified as being correct. The questions posed were those used for the subsequent explanatory case studies (see Appendix C.6). These questions sought to determine: mathematical background, reasons for dyslexia being suspected, general difficulties encountered, whether the student had up-to-date notes, the support the student had received as a result of being diagnosed as dyslexic, whether support such as the provided software was being used, whether the support provided was adequate, the areas of mathematics where difficulties were encountered, whether tutorial support and drop-in support at the MLSC was adequate, if the delivery of mathematics was in a format that suited the student, whether the student used mind maps and if there were any forms of assessment that proved to be particularly difficult.

6.2.1 Interview with Peter

Peter recalled that during Primary/Lower School his parents were informed that he was highly disruptive in class, did not appear to pay attention and frequently wandered around the classroom. His mother was concerned about this as when she asked Peter questions he could answer them and she could not reconcile the label of 'disruptive' with her son. Peter said that at this time, "My Mum was not happy with what the school had said and pushed for support and assessment". On entering middle school (at the age of 9 - 10 years) he was unable to read or write at a level anywhere near his peer group. At this time that he was assessed as being dyslexic and received additional help with reading and spelling. Peter said, "It really helped, I came on with leaps and bounds". Peter is not aware of anyone else in his family being dyslexic. His Dad has atrocious handwriting but is an avid reader; his mother is a secretary and does not have any
dyslexia-related difficulties. He has a half-brother and half-sister, neither of whom are believed to be dyslexic.

On entering upper school (at the age of 13 - 14 years) he was assessed as having a reading age of 10 - 11 years. Peter added, "At that time, I believe I was up to scratch in everything except for reading, writing and spelling. I know that my spelling was atrocious and my word bank was limited". During the first year of upper school he received the same help as he had been given during middle school, namely weekly spelling and reading classes. For the two years preceding his GCSE examinations he did not receive any support; the school wanted him to drop his Geography GCSE whereas Peter wanted to drop French and this did not fit in with the availability of the extra support. Peter sat ten GCSE subjects (including both Geography and French) and was allowed extra time in the examinations. Peter found the extra time to be particularly helpful in the English and Geography examinations. He obtained an A* for Chemistry, grade A’s for Physics, Mathematics, and Design and Technology, grade B’s for Biology, Geography, Art and English Literature, grade C for English Language and grade D for French.

During his A Level study he did not receive any additional support from the school or additional time in the examinations. His A Level tutor explained that due to his good GCSE results it would be difficult to prove that additional support was necessary. He obtained an A/S Level in Psychology at grade B and three GCSE A Levels: Mathematics and Physics at grade C and Biology at grade D. Peter also mentioned that during his A Level study he had family problems which adversely affected his concentration and he is of the opinion that without these problems he would have obtained better results.

Peter was uncertain about what to study at university. He wanted to undertake a degree in engineering but was worried about the amount of reading that this might entail. He finally decided to read for a degree in Mathematics. He applied to Loughborough and two other universities. He received the same offers from Loughborough and one of the other universities, and a lower offer from the third university. Peter explained, "I liked the look of Loughborough and came here to do Mathematics".
Peter completed the first semester of his first year and achieved quite good results. However, he was unhappy with some of the modules and recalls that he was concerned about what use topics such as real numbers would be for his future employment prospects as he did not wish to pursue a career in teaching or academia. He decided to change courses and read for a degree in Mechanical Engineering.

During his first year at Loughborough he was re-assessed for dyslexia, as his previous assessment had been undertaken when he was a child. The EP report confirmed that he was dyslexic and he was subsequently provided with extra time in examinations, a computer plus software, a note taker and one-to-one tutorial support. This support was in place when he started his new course. Peter has found the one-to-one mathematics support and the computer to be very helpful. He also benefits from having a note taker as he can now just sit and listen in lectures. There have been occasions when the note taker has failed to turn up and on some of these occasions Peter did not realise this had happened until after the lecture. In such cases he often forgot to obtain the notes from another student and failed to realise that he had an incomplete set of notes. Regarding the software that he has been supplied with, Peter has occasionally used ‘Inspiration’ to draw a flow chart but has never used the software that ‘talks back’ what has been typed. Peter has also been offered help with essay writing but has not availed himself of this support as he feels that he can manage without it. He has found the help he has received to be adequate for his needs but would like to have one-to-one weekly meetings with his personal tutor.

Peter has encountered some difficulties that have impeded his progress whilst at university. Some of these have been related to the social life that abounds at university, the peer pressure to go out and socialise, and the need for self-motivation. Peter explained that during his time studying mathematics he worked conscientiously but during the first year of his Mechanical Engineering course he realised, “I could get away with not working all the time”. He found it tempting to go out rather than study if he was aware that others had not done the work either. Moreover, if he was working and his housemates called in for a chat he then stopped working, he added, “I also found it difficult to sit down and read off my own bat”. During the second year of his Mechanical Engineering course he became much more focused and has worked
consistently. He explained, "I'm OK once I’m into the flow of the work, my confidence grows and then I can roll with it".

In addition to the difficulties associated with being responsible for his own study, he has found modules that require extensive reading to be particularly arduous as they are extremely time consuming for him. He explained, “I need to read and re-read material many times to absorb it especially when it contains subject specific jargon”.

Regarding mathematics, Peter recalled that he has experienced particular difficulties with integration. He explained, “It took me ages to get my head round integration by parts and integration by substitution”. With multi-stage operations, Peter explained, “I’m OK once I can remember all the steps, the hardest thing is getting it into my long term memory”. With text-based questions he often finds it hard to understand exactly what is being asked and in examinations he leaves these questions until last. He has also experienced difficulty with mathematical notation when symbols are used in more than one context. For example, if omega is used to mean something other than angular velocity he becomes confused and finds it difficult to follow routine procedures until he understands what is happening. Peter also mentioned, “When I’ve revised for exams I can hold material in my short-term memory long enough to complete the examination but I forget it immediately afterwards. It’s strange because I’ve got really good long term memory for faces”.

Peter could not recall obtaining incorrect answers for any areas of mathematics that he understood but then added, “I do make a lot of computational mistakes”. He further explained:

I was very competitive at school and was in the top sets for maths and physics. My mates all did numerical computation in their heads and I always tried to do the same, I felt that if they can do it so can I. I grew up feeling that it’s babyish to use a calculator for simple numerical work. What I tend to do is work really quickly so I don’t forget what I’m doing and where I’m going but I’m aware that I make a lot of mistakes.
Peter feels that the speed of delivery in mathematics lectures is about right considering the amount of material that needs to be covered. However, he also said, "I would prefer a slower delivery as this would enable me to think things through but I realise that this isn’t viable”.

The mathematics tutorials were able to address most of the remaining difficulties that he still had after his one-to-one support, as there was time available in them to ask questions. He has used the MLSC on numerous occasions, especially during the first year of his mechanical engineering course. He found it to be a good working environment and the staff very helpful. He added, “Everyone else in there is seeking help so you feel OK about asking questions and it’s good to be pointed in the right direction”. Peter was able to obtain enough help in the MLSC, although he added, “You need to attend frequently to ensure that you’re there when it’s not busy, as that’s when you get loads of help”. Peter believes that the support he has received has been adequate for his needs but pointed out, “I was OK because I had one-to-one support, without this I don’t think the time available in tutorials and the MLSC would have been adequate for my needs”.

Peter prefers a diagrammatic delivery of material wherever this is possible, with a small amount of text to add further clarification. Like Patrick, in addition to fully-worked examples, he needs an explanation as to how a particular topic is related to the mathematics he has already encountered, and also an explanation of the mathematics that can be used to solve it. He finds bullet points easy to follow, especially if they are followed by worked examples. What he finds particularly difficult is huge blocks of text. His mathematics modules have been delivered in a format that he is comfortable with. He explained that the lecturer does worked examples and provides an adequate explanation of what a particular method or topic is used for. He has found difficulty with some modules that, “Contain a lot of jargon”. Regarding the means of delivery, Peter has no real preference. His understanding remains the same regardless of whether the material is delivered by writing on an OHP or blackboard, by using transparencies or PowerPoint. He added, “PowerPoint can make a nice change as long as it’s not just click, click, click. What’s most important is that there’s a fully worked example”.

- 149 -
The form of testing that Peter mentioned as being difficult was that of negatively marked multiple-choice examinations. He explained that when faced by several similar options he lacks confidence in the answers that he has obtained and when a test is to be negatively marked this makes him extremely anxious. What then occurs is that he attempts each question several times and subsequently is unable to complete the paper in the time available.

Peter uses mind maps, which he draws himself on A3 paper. He explained:

I draw a mind map for each topic and before the examination period I do one that summarises the content of each module. They take me ages to do but they really help me with my revision. It is the process of drawing them that helps get it [the material] into my head and helps me to understand it. I find it much easier to hold things in my head as pictures.

After being assessed for dyslexia at school it was recommended that Peter should use blue-tinted glasses. He used these for a short period of time but soon abandoned them as his peer group teased him. At university it was suggested that he use a peach coloured overlay. Peter has not used one as he considers them to be, "Too much hassle for a negligible bit of benefit. Not only would I feel silly using it but it's something else that I'd have to try and remember and they're not convenient when I need to annotate handouts". Peter has no reservations about academic and academic-related members of staff being notified that he is dyslexic.

6.2.2 Report from the Mathematics Learning Support Centre

Peter was supported with three mathematics modules and it was evident that there were specific operations where he encountered difficulty. He lost his place when using tables and when scrolling down a computer screen, and lost track of where he was going in multi-stage operations. In support sessions he was encouraged to develop compensatory strategies such as writing down the main steps that need to be undertaken and started to employ this strategy. He is industrious and appears to be enjoying his mechanical engineering course but admits that he finds it a struggle.
6.2.3 Report from the Educational Psychologist

The EP’s report showed that Peter has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 110, which is above 75% of his age peers. It describes Peter as having relative strengths in working memory, perceptual organisation and basic number skills. His relative weaknesses are in verbal reasoning, phonological awareness and long-term memory. The report grouped Peter’s results into four cluster groups (see Table 12) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>53&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>81&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>88&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>58&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 12: Peter’s Cluster Group Scores from the Educational Psychologist

As can be seen, Peter’s verbal comprehension index and processing speed index are low compared to his working memory index and perceptual organisation index. As witnessed by the author of this thesis, he experienced difficulty with processing the information in text-based questions and undertaking multi-stage mathematical operations, which are linked to his low processing speed index.

The report recommended that Peter be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, computing equipment with appropriate software and a note taker.

6.2.4 Working with Peter

Peter was mathematically competent; he had commenced his undergraduate studies reading for a degree in mathematics. Nevertheless, he did encounter problems even though his mathematical ability exceeded that which was required for his Mechanical Engineering course.
It is of interest that during the interview with Peter he referred to his aversion to using a calculator for what he considered to be basic computation. During support sessions it was apparent that this was indeed the case. At the onset of supporting Peter it was noticeable that he had a tendency to rush through calculations; he was writing down a minimum amount of computation and relying on mental arithmetic. The subject of using a calculator was raised and Peter’s responses, at subsequent support sessions ranged through, “I’ve left it in my room”, “It’s in my bag but it needs new batteries” to finally, “I’ve got it with me, it’s got new batteries, it’s on the desk and I’ve switched it on”. This was a major breakthrough as at an earlier support session the author of this thesis had, along with Peter, been independently computing a 3x3 matrix question to determine that $P^{-1}AP$ was diagonal. We were both, on this occasion, working without calculators to compute the RHS of:

\[
P^{-1}AP = \frac{1}{6} \begin{bmatrix}
-1 & -2 & 7 \\
3 & 0 & -3 \\
-2 & 2 & 2
\end{bmatrix} \begin{bmatrix}
1 & 1 & -2 \\
-1 & 2 & 1 \\
0 & 1 & -1
\end{bmatrix} \begin{bmatrix}
1 & 3 & 1 \\
0 & 2 & 3 \\
1 & 1 & 1
\end{bmatrix}
\]

Peter completed the multiplication of the RHS of the equation more quickly that the author of this thesis and obtained a different answer. A comparison of computation was difficult as Peter had not written down anything other than the result of each matrix multiplication and it was difficult to determine if he had multiplied the matrices correctly or had made numerous errors. To make comparison easy, should different answers be obtained, the author of this thesis had written down all stages of her working as demonstrated below.

\[
P^{-1}AP = \frac{1}{6} \begin{bmatrix}
-1 & -2 & 7 \\
3 & 0 & -3 \\
-2 & 2 & 2
\end{bmatrix} \begin{bmatrix}
1 & 1 & -2 \\
-1 & 2 & 1 \\
0 & 1 & -1
\end{bmatrix} \begin{bmatrix}
1 & 3 & 1 \\
0 & 2 & 3 \\
1 & 1 & 1
\end{bmatrix}
\]

\[
= \frac{1}{6} \begin{bmatrix}
-1 & -2 & 7 \\
3 & 0 & -3 \\
-2 & 2 & 2
\end{bmatrix} \begin{bmatrix}
1-2 & 3+2-2 & 1+3-2 \\
-1+1 & -3+4+1 & -1+6+1 \\
-1 & 2-1 & 3-1
\end{bmatrix}
\]

- 152 -
It was determined that Peter had multiplied the correct rows and columns but had made many computational errors. As a result of this, not only was Peter encouraged to use a calculator but also considerable time was spent encouraging him to write down all stages of his working out. It was pointed out to him that he should do this in examinations as it would enable the person marking his script to determine where an error had occurred and whether this was due to a calculation mistake or lack of understanding. At the end of the semester when Peter was working on past examination papers he used his calculator diligently and recorded all stages of his working out.

He also encountered difficulties with the lengthy text in statistical questions. It was noticed that when attempting such questions he needed to read through the text as many as three times and this was undertaken very slowly. Peter explained that he needed to do this to absorb and understand what the question was asking, he added, “I get part way through and lose track of what I have read”. Peter also added “In examinations I only do statistics questions if they are compulsory, they take me ages to do”. Unlike Patrick, Peter did observe information such as ‘with’ or ‘without replacement’ and correctly followed instructions such as, ‘find the probability that at any given time at least one component is working’. Nevertheless, it was apparent that Peter needed to spend a disproportionate amount of time on these questions. Not only did it take him a long time to comprehend what was being asked but he also checked any figures he obtained from the statistical tables several times as this was an operation where he tended to make mistakes. He was encouraged to highlight or underline all key words in a question during his first reading of it and then to re-read the question. This did prove to be helpful but nevertheless undertaking statistics questions was still a lengthy procedure.

Peter also encountered problems with Fourier series, albeit of a different nature to those experienced by Patrick. Peter did not fail to compute all the required stages but often undertook unnecessary calculations. For example, he did not pay any attention to whether a function was odd or even and always calculated all of the terms $a_0$, $a_n$ and $b_n$. Time was spent with him to determine whether he could distinguish between such

\[
\frac{1}{6} \begin{bmatrix}
-1 & -2 & 7 \\
3 & 0 & -3 \\
-2 & 2 & 2
\end{bmatrix} \begin{bmatrix}
-1 & 3 & 2 \\
0 & 2 & 6 \\
-1 & 1 & 2
\end{bmatrix}
\]
functions and he was able to identify correctly all the functions that he was presented with. It transpired that his concern was that if he had to focus on all the information contained within the question he would need to read it several times. Moreover, he would then be faced with different options and feared that he would get mixed up with the computational process. He explained, “There are too many possible variations, I just can’t remember all the things I’m supposed to be taking into account so it’s easier just to work out everything”. It was suggested to Peter that Fourier series questions should be broken down into two distinct operations like statistics questions whereby he read the question and underlined the key components. In the case of Fourier series the first task was to determine if the given function was even, odd or neither and annotate the question accordingly. A memory aid was devised as shown in Figure 13 to help Peter recall what he had to calculate.

\[
\text{EVEN} = \text{an even function} = a_n \text{ terms} \\
\text{ODD} = \text{an odd function} = b_n \text{ terms}
\]

Figure 13: A Memory Aid for Even and Odd Fourier Co-efficients

The second stage would be for Peter to undertake the required calculations. This approach of breaking down a large amount of processing into two smaller operations was successful and Peter was able to assess what was actually required before undertaking any computation and thus avoided making mistakes and wasting time on unnecessary working out.

In addition to computational errors, Peter also made a lot of transcription errors, i.e., subscripts were omitted and an \( x^2 \) after a few lines of working could become \( x^3 \). The greatest problem Peter encountered was in solving systems of coupled equations. The following question highlights the areas where he encountered difficulty.

**Question:** The motion of two masses \( m_1 \) and \( m_2 \) vibrating on coupled strings, neglecting damping and spring masses, is governed by:

\[
m_1 \ddot{y}_1 = -k_1 y_1 + k_2 (y_2 - y_1)
\]
Write this system as a matrix equation $\mathbf{Y} = A\mathbf{Y}$ and use the decoupling method to find $\mathbf{Y}$ if:

$m_1 = m_2 = 1, \ k_1 = 3, k_2 = 2,$
and the initial conditions (IC’s) are
$y_1(0) = 1, \ y_2(0) = 2, \ \dot{y}_1(0) = -2\sqrt{6}, \ \dot{y}_2(0) = \sqrt{6}$

Once it was realised that Peter frequently made mistakes with the subscripts, we tried to eliminate them wherever possible, for example the solution was commenced with:

Let $y_1 = x$
$y_2 = y$

Peter could then proceed to obtain the eigenvalues and corresponding eigenvectors. After a little practice and by referring to a model answer with colour coded prompts he was able to work through the stages of $\mathbf{Y} = D\mathbf{Y}, \mathbf{X} = P\mathbf{Y}$ to obtain:

$$x = -2(A\cos(\sqrt{6}t) + B\sin(\sqrt{6}t)) + C\cos(t) + D\sin(t)$$
$$y = A\cos(\sqrt{6}t) + B\sin(\sqrt{6}t) + 2(C\cos(t) + D\sin(t))$$

He did not experience any problems, other than transcription errors, when using the IC’s and solving simultaneously to obtain $A$ and $C$.

$$x = -2B\sin(\sqrt{6}t) + \cos(t) + D\sin(t)$$
$$y = B\sin(\sqrt{6}t) + 2\cos(t) + D\sin(t)$$

These equations then needed to be differentiated and the second set of IC’s inserted into them. However, by the time Peter had undertaken the necessary computation and established values for $B$ and $D$ he had turned over one or more pages and lost sight of the equations into which he should be substituting the values. What often occurred was that he substituted $B$ and $D$ into the differentiated equations, failing to notice the dot
over the $x$ and $y$. It was suggested that after finding the first two constants a big coloured box should be drawn round the two resulting equations prior to differentiating.

Peter, and Patrick, often failed to use the answers they had obtained in an early part of a question, even when explicitly told to do so, as a basis for answering the latter part of a question. They both found it too difficult to keep their mind focused on what the question required and at the same time ascertain at what stage of a process they should then commence from. They were advised to take a step back from the question and to write down what they had determined in the early part of the question, what was required in the latter part of the question, and to look for a process that would take them from the early part of the question through to the latter part. It was stressed that the earlier results should be incorporated part way into the process they had identified and this would be the starting point for their computation. This approach was partially successful but there were many occasions when the situation was likely to arise and these involved many different topics and procedures. There were also some multi-stage operations which both Peter and Patrick had difficulty in undertaking if they did not compute the question from the beginning.

Another variation of this difficulty, for both Peter and Patrick, was that if in a latter part of a question it was expected that earlier findings should be used but this was not explicitly stated then they frequently failed to recognise that this was required. To deal with this situation they were both told to look at the marks awarded for each part of a question and to use this to guide them as how much working out was expected to be undertaken. This approach was successful to the extent that both students realised they were not expected to undertake a lengthy calculation for a part of the question that only offered low marks. Nevertheless, they sometimes found themselves at a loss as how to proceed or repeated their earlier calculation.

At the start of a topic Peter asked to be given a fully-worked model solution, which he used as a template for future questions. After completing a few questions he then wrote down the main steps and used this as a memory aid. He is emphatic that the colour coded model answers were extremely helpful to him and in examinations he was able to picture them along with his mind maps. Like Patrick, much repetition of material was required.
Peter is now in the final year of his degree programme.

6.3 Working with Russ

Russ displayed difficulties of a similar nature to those encountered by both Patrick and Peter. The severity of the visual disturbance that he encountered appeared to be greater than that encountered by Patrick and Peter. His mathematical ability was good but he had to be frequently reminded as to how to undertake particular methods and his recall of formulae was extremely poor. It appeared that it was very difficult for him to place information in his long-term memory. He had one particularly notable shortcoming. This was discerning between differentiation and integration. He was able to differentiate and integrate at the level that was required by his course but found it difficult to relate the command to the required operation. It was suggested to Russ that differentiation began with a ‘d’ and this required him to decrease the power by one. This suggestion was successful and Russ was subsequently able to distinguish between the two operations.

His mathematical problems were also compounded by his mental health difficulties. Some weeks Russ would turn up for his support sessions with evidence of having attempted or completed tutorial sheets, yet on other occasions it was apparent that he had not done any work since the previous session. Like Patrick and Peter he tended to rush through computation, which resulted in many transcription errors being made.

Progress with Russ was inevitably slow, not only was much repetition of material required but on many occasions he was extremely anxious when he arrived and it was considered important that every session should end on a positive note. He not only had problems with note taking but also with organising his notes. Notes from different modules were frequently mixed together and often did not include any information such as the module name or date. Time was spent emphasising the importance of clearly labelling and filing notes and it was suggested that he obtain a hard backed book without detachable pages. Russ adopted this method, using one book for each module. This resulted in each module being distinct and whilst his notes were messy and sometimes incomplete they were at least in date order. In the main, the support that was
given to him was in the form of providing worked examples, which contained a lot of colour, diagrams, and rhymes that were devised to aid his memory recall. Russ did not use mind maps but was encouraged to draw diagrams or flow charts in an endeavour to help him to remember processes, especially those encountered in multi-stage operations where he frequently lost track of where he was going. He did adopt this idea and found it to be helpful.

He found the MLSC to be daunting due to the number of different lecturers that worked there. He found the tutorials less daunting, as he met the same person each week, but there was insufficient time available to obtain the help that he needed. Russ was grateful for the one-to-one support that he received and found it to be beneficial. Not only did he find that his mathematical competence improved but also that he became more confident in his attempts to solve problems and tended to persevere for longer. He was of the opinion that he required this form of support with some of his other modules.

Russ decided not to continue with his course and withdrew from university.

6.4 Triangulation of Data

Like the exploratory studies (Chapter V) there is evidence of corroboration between what the students reported, what the EP’s determined and what was observed during one-to-one support. For example, Patrick’s EP report described him as having strengths in visual working memory. Patrick referred to this when he explained that he could visualise his mind maps in examinations. Patrick described himself as having difficulties with multi-stage operations, with isolated topics, with reading from statistical tables, and being extremely anxious when undertaking examinations; all of which was observed during the one-to-one support sessions.

Peter’s EP report described him as having weakness with long-term memory and Peter also referred to this. It was also mentioned by Peter that he was concerned about the amount of reading an engineering degree would entail, the EP report determined that his processing speed was slow and this was observed by the author of this thesis and a member of the MLSC who supported Peter with earlier modules.
6.5 Findings from the One-to-One Support Case Studies

The research design for the one-to-one case studies (see Appendix B.2) contains seven hypotheses. Using cross-case synthesis the findings from the one-to-one support case studies are linked to these hypotheses. To increase validity, most of these hypotheses will be investigated again in the explanatory multiple-case studies (see Chapter VII).

Hypothesis 1: Dyslexic students experience difficulty with note taking.

All three of the students who received one-to-one support experienced difficulty with note taking. This is in accord with the exploratory case studies where it was determined that all six of the students experienced difficulty in this area. However, it is pertinent to mention that this ceased to present a problem for Patrick once he had a recording device and for Peter once he had a note taker.

Hypothesis 2: Dyslexic students experience difficulties with multi-stage mathematical operations.

Again, all three of the students experienced difficulties with multi-stage operations.

Hypothesis 3: Some dyslexic students experience visual problems, which results in difficulties being encountered when working with rows and columns of figures or equations.

All three of the students encountered visual problems in these areas.

Hypothesis 4: Dyslexic students experience difficulties with lengthy descriptive text.

All three of the students encountered difficulties when they were faced with lengthy descriptive text. This is in agreement with the exploratory multiple-case studies where it was determined that all the participating students struggled with reading and recalling material.
Hypothesis 5: Dyslexic students experience difficulties with the application of notation and recall of formulae.

Patrick and Peter both had difficulties with the application of notation and all three of the students had problems recalling formulae prior to memory aids being devised for them. This is in accord with the exploratory studies where half of the participating students were found to experience difficulty with the recall of formulae and/or theorems.

Hypothesis 6: Drop-in support at the MLSC is inadequate for dyslexic students.

Russ found that the support in the MLSC was unsuitable for his needs due to the fact that he encountered so many different lecturers. Patrick and Peter found the MLSC to be extremely helpful but added that it would have provided insufficient help had they not been receiving one-to-one support.

Hypothesis 7: Dyslexic students may be helped to overcome their mathematical difficulties.

Through the provision of one-to-one support it is evident that if dyslexic students are given assistance to develop compensatory strategies they may be helped to overcome many of their difficulties. Furthermore, the students found the one-to-one support to be extremely beneficial to them.

The findings from the one-to-one support cases studies suggest that there is evidence to support all seven of the hypotheses. These findings are further validated by the evidence from the explanatory multiple case studies (see Chapter VII).

6.6 Conclusion

Two questions were posed and answers to these questions have been obtained. Question 1 asked how dyslexia impedes the learning and understanding of mathematics and question 2 sought to determine how dyslexic students might be helped to overcome their difficulties.
Regarding Question 1, it has been shown that dyslexia has the potential to cause difficulties with:

- The reading and comprehension of text based questions
- Note taking
- Use of notation and recall of formulae
- Use of statistical tables and working with rows and columns of figures
- Multi-stage mathematical operations
- Isolated topics
- Numerical computation.

Regarding question 2, it has been shown that dyslexic students can be helped to overcome their difficulties by:

- Breaking down multi-stage operations into smaller more manageable tasks
- Supplying rhymes and visual aids to memory
- Determining the best use of extra time in examinations and examination techniques
- Supplying fully worked colour coded diagrams
- Explaining how topics interrelate and providing a more global picture
- Encouraging students to use squared paper
- Providing simple 3-d models
- Encouraging the use of mind maps and diagrammatic representation.

Overall, it was found that a great deal of patience is required, topics need to be frequently revisited, multi-stage operations need to be broken down into smaller sections, and strategies devised to aid memory recall. This is in agreement with that which is advocated by T.R. Miles (1992:86-91).

Moreover, the difficulties with note taking can be alleviated by the provision of additional support. This may be achieved by providing the student with a note taker or a recording device, depending upon what is deemed to be necessary. It is of interest, and importance, that Patrick and Peter found the tutorial support and the MLSC to be adequate for their needs only as a result of being provided with one-to-one support. Without this one-to-one support they expressed the opinion that it would have been inadequate. Russ found the MLSC to be daunting due to the number of different staff
who worked there. The suitability of the MLSC for dyslexic students will be discussed further in Chapters VII and IX.

One area of concern that will be explored further in the explanatory multiple-case studies (see Chapter VII), is that the students were not making use of the software that had been supplied to them. They preferred to draw their own mind maps as they considered this to be part of their learning process, they did not use the talk back software and chose not to use the coloured overlays that it had been suggested that they use.

Other areas of concern, reported by the students, were related to multiple-choice examinations and CAA. Difficulties with assessment will be explored further in Chapter VII. CAA was found to present problems to Patrick and also to Alan (see Chapter VII) and this means of assessment was further investigated and is reported in Chapter VIII.
The explanatory case studies

The questions posed for the explanatory case studies, which were undertaken during the academic years 2004/2005 and 2005/2006, were to determine how dyslexic students are impeded in their learning and understanding of mathematics and how these students might be disadvantaged by current practices of material delivery and examination procedures within Loughborough University. Unlike the exploratory case studies, all the participants are undergraduate engineers. In addition to the 12 explanatory case studies undertaken with dyslexic students, which include one student who probably has ‘acquired dyslexia’ arising through a head injury, a control group of 12 non-dyslexic engineering undergraduates were also interviewed. The control group was included in order to determine if there were any differences in approach to learning and revising, and areas of difficulty that were experienced, between the two groups, and also to increase internal validity.

As mentioned in Chapter IV (section 4.4) there was some difficulty in finding a sufficient number of students willing to take part in this research. Initially it was intended to include only students who had been diagnosed as dyslexic after commencing their undergraduate studies but, due to a lack of participants, some students who had been diagnosed as dyslexic prior to entering university have been included. Of the dyslexic students, six were diagnosed as dyslexic after entering university and six were diagnosed as dyslexic whilst at school. All participating students (dyslexic and non-dyslexic) received a small honorarium.

Of the dyslexic students who participated in these studies, two were approached by a member of the ELSU and one by a member of the MLSC. The remaining ten students were in timetabled tutorials that were being conducted by the author of this thesis and volunteered, in response to a request for volunteers that had been made. All the non-dyslexic students who participated were in the tutorial sessions being conducted by the author of this thesis.
Each student was interviewed once and a narrative of each interview is given. The dyslexic case studies also include a report from a member of the MLSC and/or a member of the ELSU (if the students were known to them). A précis of the EP report is included if available and if the student has consented to access being given. Sections 7.1 - 7.13 detail the dyslexic case studies, section 7.14 contains narratives from the semi-structured interviews with the non-dyslexic students, section 7.15 reports the findings from the studies and section 7.16 contains the conclusion.

The questions posed may be viewed in Appendix C; the dyslexic students were asked all of the questions, whereas the non-dyslexic students were asked only those questions shown in bold font (the questions in non-bold font being inapplicable).

For the dyslexic and non-dyslexic students the questions sought to determine the following: course of study, educational background, general difficulties encountered whilst at university and the nature of these difficulties, whether they had up-to-date notes taken by themselves, areas of mathematics that posed particular difficulty, areas of mathematics for which incorrect answers were obtained even though they believed that they understood the topic, a description of the speed of delivery in lectures, the usefulness of the tutorials, whether the MLSC has been visited and if so its effectiveness, the best medium of delivery of material, types of assessment that proved difficult, and whether mind maps were used for mathematics.

In addition the dyslexic students were asked what led to them suspecting that they were dyslexic, what help they had received as a result of being diagnosed as dyslexic and whether this help was adequate, whether they used any software that had been provided for them through the DSA, whether they were willing for academic and academic-related staff to be made aware of their dyslexia, if they had received both one-to-one mathematics support and dyslexia-dedicated support, which was the most useful and finally, if they had been given coloured overlays whether or not they used them.

The research questions that were posed for the explanatory multiple-case studies are:

1. How does dyslexia impede the learning and understanding of mathematics for engineering students in HE?
2. How are dyslexic engineering students disadvantaged by current practices of material delivery and examination procedures within Loughborough University?

From these questions, ten hypotheses were formulated:

Hypothesis 1: Dyslexic students experience difficulties with note taking.
Hypothesis 2: Dyslexic students experience difficulties with multi-stage mathematical operations.
Hypothesis 3: Some dyslexic students experience visual problems, which result in difficulties being encountered when working with rows/columns of figures and equations.
Hypothesis 4: Dyslexic students encounter difficulties with lengthy descriptive text.
Hypothesis 5: Dyslexic students experience difficulties with the recall of notation and formulae.
Hypothesis 6: Tutorial support is inadequate for the problems experienced by dyslexic students.
Hypothesis 7: Drop-in support at the MLSC is inadequate for the needs of dyslexic students.
Hypothesis 8: Some methods of mathematics delivery and assessment are unfair to dyslexic students.
Hypothesis 9: Dyslexic students learn and revise differently to non-dyslexic students.
Hypothesis 10: Dyslexic students may understand some areas of mathematics but obtain incorrect answers.

As mentioned earlier, it is the acceptance or rebuttal of each hypothesis that will determine the answers to the research questions.

It is easily envisaged that dyslexia might cause problems with note taking, and this was confirmed by the exploratory case studies (see Chapter V). However, there are many other areas that pose difficulties to the dyslexic student. What emerges from these case studies and the interviews with the non-dyslexic students are the differences between these two groups and the many areas in which dyslexia has the potential to impede progress.
All the students participating in this research signed consent forms and verified, at the time of the interview, that what had been written was correct. To protect the identities of all participants, pseudonyms, which do not necessarily depict their true gender, have been used. The ratio of male/ female participants has, like the earlier studies, been maintained.

The dyslexic students who participated in these explanatory case studies, and the non-dyslexic students who formed the control group came from several different departments at Loughborough University. These are shown in Tables 13 and 14.

<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Aeronautical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Phyllis</td>
<td>Civil Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Stuart</td>
<td>Civil Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Alan</td>
<td>Civil Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Daniel</td>
<td>Institute of Polymer Technology and Materials Engineering (IPTME)</td>
<td>First year</td>
</tr>
<tr>
<td>Chris</td>
<td>Electronic and Electrical Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Anthony</td>
<td>Mechanical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>James</td>
<td>Electronic and Electrical Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Jack</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Bob</td>
<td>IPTME</td>
<td>First year</td>
</tr>
<tr>
<td>Joseph</td>
<td>Civil Engineering</td>
<td>Final year</td>
</tr>
<tr>
<td>Lee</td>
<td>Civil Engineering</td>
<td>First year</td>
</tr>
</tbody>
</table>

Table 13: Dyslexic Students Participating in the Explanatory Studies
<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan</td>
<td>Aeronautical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Trev</td>
<td>Aeronautical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Dev</td>
<td>Civil Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Gary</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Bella</td>
<td>Aeronautical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Wayne</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Rachel</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Nico</td>
<td>Aeronautical Engineering</td>
<td>First year</td>
</tr>
<tr>
<td>Andrew</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Jon</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Brad</td>
<td>Civil Engineering</td>
<td>Second year</td>
</tr>
<tr>
<td>Barry</td>
<td>Civil Engineering</td>
<td>First year</td>
</tr>
</tbody>
</table>

Table 14: The Control Group of Non-Dyslexic Students

### 7.1 Case Study 1: Edward

Edward, an international student, came to Loughborough University when he was 18 years old to undertake a foundation course. He was interviewed after being diagnosed as dyslexic during the first year of his Aeronautical Engineering course. The following section includes all the information that was recorded during one interview, which Edward verified as being correct.

#### 7.1.1 Interview with Edward

It was suggested to Edward that he might be dyslexic by a friend on his foundation course who had dyslexic friends. Edward explained that he was experiencing short-term memory problems and was unable to recall material unless it had been frequently repeated. He successfully completed his foundation course and during the first year of his Aeronautical Engineering undergraduate programme made an appointment at the ELSU and was given a DAST. This screening process suggested that he was dyslexic.
However, he was not referred to an EP, as funding for this is not available for international students.

Edward cannot simultaneously take notes in lectures and listen to what is being said. These difficulties cannot be attributed to his being an international student as his earlier education was conducted in English. In examinations he found time to be a problem; he explained, “My writing is OK except at speed but in exams I start to panic about not completing the paper and once I start to panic my mind just goes blank”. He has now been awarded extra time in examinations and this has been beneficial to him. Edward has not encountered any other difficulties of a more general nature that have impeded his progress.

Edward does have an up-to-date set of notes for his mathematics modules; these are comprised of notes handed out by the lecturer, workbooks and his own notes that he has taken in lectures. He uses a yellow overlay in lectures, examinations and at home as this helps to alleviate the glare from printed pages that he experiences.

Edward has received some one-to-one mathematics support, which was provided by a member of the MLSC and also attends the Wednesday afternoon workshops organised by a member of the ELSU for dyslexic and dyspraxic students. Edward is aware of computing programmes to assist dyslexic students that can read back work but does not feel that they are suitable for engineering courses. He believes that the help he has received has been adequate for his needs.

The area of mathematics that has proved most problematic for Edward is calculus, especially integration by parts and solving differential equations. He explained that it is these multi-step problems where he experiences the greatest difficulty. He understands questions relating to distance, velocity and acceleration but frequently obtains incorrect answers. Likewise, when working with matrices his answers were again often incorrect and the larger the matrix, the greater was his chance of obtaining an incorrect answer. To avoid visual disturbance he needs to leave lots of space between each row of working and this then compounds his problems as he is frequently turning to a new page.
He finds the speed at which lectures in mathematics are delivered to be too fast. He attends the timetabled tutorials for his mathematics modules and explains that these are sometimes sufficient to address his needs but not when there is a high student attendance. When this occurs he contacts the lecturer for help with any remaining problems he still has.

Edward frequently attended the MLSC drop-in sessions during his foundation year and occasionally during his first year. The help he obtained in the MLSC was sometimes sufficient but not when the Centre was busy as the lecturer on duty was then unable to spend enough time with him. Edward has found the MLSC to be busier this year than during his foundation year and feels that it is the one-to-one mathematics support that is really helping him.

Edward initially felt confused and scared when it transpired that he was dyslexic. However, he felt better after he had talked to a member of the ELSU and was relieved to find that there was an explanation for his difficulties. He is willing for academic and academic-related staff to know that he is dyslexic.

Regarding the delivery and presentation of material in lectures, Edward prefers the material to be presented step-by-step, well spaced and delivered via an OP with additional information and equations written on a black/white board at a realistic speed. Generally, he finds that the delivery of material is not the way he would like it to be. He finds small writing, closely written lines and writing that is not neat particularly difficult to follow. Additionally, he needs a clear, fully-worked example to demonstrate any theoretical material.

Edward is comfortable working on computers and undertaking CAA. He experienced problems with multi-choice tests, where he found that there were too many boxes too close to each other on the page. He explained, "It all started to look fuzzy as I marked in my answers, I lost my place and made mistakes".

A member of the ELSU has given him information on the use of mind maps to aid him in his recall of methods and procedures. He has found this to be particularly helpful with work conducted in the laboratory and now uses mind maps for mathematics. He
does not use the software he was provided with; he prefers to draw them himself as, "This helps me to learn and remember".

7.1.2 Report from the English Language Study Unit

The DAST showed Edward to have an at risk quotient of 1.3, which is a strong indicator of dyslexia (Chapter III, section 3.6.1), but, as he is an international student, there was not any funding available for him to be referred to an EP.

Edward needed to re-sit four modules at the end of his foundation course, namely, physics, engineering, and both mathematics modules. He passed these re-sit examinations and progressed to the first year of an Aeronautical Engineering programme. Edward appeared to be very bright, he was a fairly quiet student but what he said was to the point. He attended the Wednesday afternoon dyslexia and dyspraxia workshops and helped other students. He had been educated in English and therefore did not have any difficulty in understanding the English language.

After the first semester examinations he appeared to be happy but subsequently failed the first year of his course and did not return to university.

7.1.3 Reports from the Mathematics Learning Support Centre

The member of staff who supported Edward during his foundation year described Edward as having short-term memory limitations, which resulted in him experiencing great difficulty with many areas of mathematics and he had to undertake re-sit examinations at the end of his foundation year.

The member of staff who supported Edward during the first year of his Aeronautical Engineering degree programme reported that Edward was only seen twice and did not appear to have any difficulties with the material he was encountering at the time. Edward felt that he was coping and did not feel the need for support at this time. It was agreed that he should return for support if he encountered any problems.
Phyllis is an undergraduate in the Civil Engineering Department. She was interviewed during the first year of her MEng course, which she commenced when she was 19 years old. The results of screening for dyslexia were inconclusive, showing a marginal result. Five years before entering university she had sustained a serious head injury and had been informed that she may possibly experience memory problems as a result of this. The following section includes all the information that was recorded during one interview, which Phyllis verified as being correct.

7.2.1 Interview with Phyllis

Phyllis explained that she kept forgetting things; her memory recall and handwriting skills were also poor. She made an appointment at the ELSU and subsequently spoke to a member of this department. The result of the DAST was inconclusive showing that she was a marginal case. As a result of her previously mentioned head injury she was in intensive care and was in a coma for five days. It was suggested by the member of the ELSU that she obtain a report from her doctor. Phyllis obtained a medical report detailing her injury, which she gave to a member of the DANS, and she now receives extra time in examinations.

Whilst at university she has encountered some problems. In fluid mechanics she had difficulty in recalling formulae and what the letters in the formulae represented. She is also slow at taking down lecture notes, saying, "Everyone else finishes before I do". As a result of this she misses comments and explanations made by the lecturer as she is still copying from the board at the time when the lecturer is expanding upon the topic. Phyllis also experiences problems recalling information. She is now aware that this was happening whilst she was at high school but she didn't pick up on it at the time. Occasionally she checks points in her notes with those of others on her course. However, whilst her notes are messy, they are complete and up-to-date.
In addition to the extra time in examinations, she has also been offered help with revision techniques and feels that this help is adequate. She is aware of the support that is available should she require it.

Regarding mathematics, she experienced problems with numbers during her GCSE work. These problems were associated with the rounding up or rounding down of numbers, an area that she has never understood. However, she obtained a grade A in GCSE Mathematics and a grade B in A Level Mathematics. She explained that her problems with numbers are proving to be less onerous now due to more letters appearing in the mathematics she is encountering.

She expanded on her difficulties, explaining that she often, “Crams material into one line” and as a result of this she finds it difficult to see where she has gone wrong. Whilst at school she had help from her father, who is a teacher of mathematics, but he frequently used a different method to that which had been used by her teacher and this resulted in Phyllis becoming confused. Another common occurrence is that she often fails to observe minus signs in equations.

When asked if there had been any particular areas of mathematics that she understood but for which she frequently obtained incorrect answers, she again explained that it consistently happened when undertaking questions involving numbers. She also mixed up formulae, failed to recall what the letters were representing and often used an incorrect formula for the mathematical operation she was undertaking. This happened repeatedly with certain formulae she encountered in Fluid Mechanics.

She finds the speed at which lectures are delivered to be “OK”. However, regarding tutorial support she would prefer the lecturer to be available rather than a postgraduate student as sometimes occurs. Phyllis explained that in some of her tutorials the postgraduate students were mathematics rather than engineering graduates. These postgraduate students often used different methods to those used by the lecturer and also placed a different emphasis on the topics being studied. Phyllis added, “Mathematics tutorials were often poorly attended, which meant that those who did attend could obtain more help, but they [the tutorials] still didn’t provided adequate support”. She
occasionally attended the MLSC where she found the help available was sufficient to help her overcome any remaining difficulties.

Regarding the delivery and presentation of mathematics in lectures, Phyllis finds diagrammatic representation easy to follow; she describes herself as being, "A visual and audio learner". During her GCSE’s she used a Dictaphone, speaking her work into the machine and then listening to it. She explained, “If I’m reading material then it takes three times longer to go in than when I listen to it”. When lecturers are writing on the board or using an OP she feels that she would benefit from more diagrams being included.

The ways in which mathematics are tested are generally not problematic for Phyllis although she has found the multi-choice forms a bit confusing. This is due to the option boxes not having enough space between them and the similarity of the options.

Phyllis has drawn herself mind maps/spider diagrams since GCSE as they help her to relate to whole processes and also provide a link between topics. A visitor to her school suggested using mind maps to aid revision and also advocated that it was important to eat breakfast, drink plenty of water and have adequate sleep. Teachers at her school had referred to mind maps as spider diagrams and instructed pupils that each diagram should have no more than eight branches leading from the central point. She concluded the interview by describing herself as having a very competitive nature and explaining that if she doesn’t understand a topic straight away she feels frustrated.

Phyllis is now in the second year of her course.

7.2.2 Report from the English Language Study Unit

Phyllis clearly had some problems that that were characteristic of dyslexia. Her writing speed was very slow, in the 4th percentile on the DAST, but she did not have a typical dyslexic profile. An EP who specialises in head injuries was contacted and he suggested that Phyllis obtain a report from her doctor. The doctor’s report enabled an extra time
allowance in examinations to be awarded and Phyllis was also offered support with revision strategies.

7.3 Case Study 3: Stuart

Stuart is an undergraduate in the Civil Engineering Department. He was interviewed during the final year of his Air Transport Management course, which he commenced when he was 26 years old. The following section includes all the information that was recorded during one interview, which Stuart verified as being correct.

7.3.1 Interview with Stuart

Whilst at school Stuart had been labelled as bright but lazy and left school after taking GCSE’s; the highest grade that he obtained was a D. He came from an agricultural background and said “I just thought, oh well I’ll be OK in farming”. Stuart then went to Agricultural College and experienced some difficulties with the work. He recalls that he was told, “You’re just going to be a farm labourer, don’t worry about it”. He obtained National Certificate in Agriculture (NCA) and BTEC qualifications but felt that farming was not the direction he wanted to take. He then went to Norway to visit friends and stayed there for eight years, eventually becoming fluent in Norwegian. It was whilst working in Norway that he realised his promotion prospects were poor without better qualifications; he decided to return to England to read for a degree. The qualifications he had obtained at Agricultural College were equivalent to an A/S level.

His mother is dyslexic; she is artistic and also writes but experiences problems with spelling. His younger brother had experienced difficulties at school and it had been suggested that he might be dyslexic. It was a combination of his brother’s suspected dyslexia and seeing the dyslexia notices around campus that prompted Stuart to investigate the possibility that he too might be dyslexic.

He visited the ELSU, where a member of staff first talked with him and later administered a DAST. The result of this screening showed that he was considered to be
in the ‘at risk’ category. An EP subsequently diagnosed him as being dyslexic and dyspraxic, and recommended that he receive two hours of one-to-one support per week and extra time in examinations. A member of the ELSU and a member of the MLSC gave this one-to-one support as Stuart’s needs were both with his written work and with his mathematics.

Stuart recounted that he had experienced problems with note taking at university and whilst most lecturers placed their notes on the VLE (this is available to staff and students via the university web page and contains, for example, lecture notes and solutions to tutorial sheets) some lecturers, especially those who had been at the university for a long time, did not do this. He described most lecturers as being obliging. However, the Head of his Department said to him: “It is not allowable for lecturers to give you copies of overhead transparencies”. Nevertheless Stuart recounted that most of the lecturers still gave him this material.

It was with dense blocks of writing that Stuart encountered most difficulty, finding it impossible to keep pace with his note taking. Regarding the notes for his mathematics modules, Stuart described these as being up-to-date. If he has not been able to take down all the material in a lecture, he obtains the missing material by one or more of: photocopying his friend’s notes, printing the material from the VLE, visiting the lecturer concerned or consulting a textbook.

Other problems, which he encountered, were related to the sequencing of numbers and timekeeping. Whilst he did not miss any lectures, he said, “I often found myself arriving either too early or somewhat late for them”. He describes himself as frequently losing track of time. When consulting his timetable he often missed vital pieces of information, for example, a computer session that was timetabled for weeks 1 and 2 only. He expanded on his problems related to sequencing of numbers by explaining that if he read the time 10:25 and then looked away he would not be able to remember what the time was. Whereas if the time had been written as twenty five past ten he did not have any difficulty in recalling it.

Stuart needs to prepare in advance to enable himself to plan his work, thus ensuring that he does not miss any coursework submission deadlines. He explained that he enters
details of all his coursework assignments and the dates on which they are to be submitted into an ‘Excel’ spreadsheet. He uses large font in ‘Comics Sans’ with lots of colour and refers to this to plan his work schedule. For his final year dissertation, which he described as, “An overwhelming task” he chose a topic that didn’t include mathematics or statistics. The subject he selected was: ‘Why an airline went bankrupt’. This choice resulted in him receiving opposing views from two lecturers; one lecturer telling him that he would not be able to obtain top marks with this topic as there was no mathematical or statistical elements in it and the other lecturer disagreeing.

Regarding the assistance he has received, Stuart explained that he obtained one-to-one support from members of the ELSU and the MLSC up to Easter in his final year and additionally he received support from his friends, especially in statistics. He now prefers to rely on his friends for help, as this is more convenient as he is in the last few weeks of his degree programme. The extra time he is allocated in examinations has reduced the stress he used to experience as it gives him breathing space to read through the examination paper slowly and carefully. It enables him to decide which questions he can answer best; he notes down his first thoughts and key words alongside each question so that he doesn’t forget them once he becomes engrossed in answering the questions. He is also allowed a Norwegian/English dictionary as he is registered as a Norwegian student; he finds this helpful, as there are some words that he is more familiar with in Norwegian than in English. He was not eligible for technological support as he had not been resident in England for the three years preceding the commencement of his course. He has bought himself a laptop computer as he needs to work when he feels motivated, which does not always occur at convenient times.

He describes his spelling as “pretty bad”, explaining that when he is writing he uses the motor memory in his hand to guide him rather than his mind, but this goes wrong if he tries to think about the actual word. When using a word processing package such as ‘Word’, his spelling is much better as he has in his mind a pattern of where the keys are.

Stuart does not feel that the help he has received was adequate for his needs as his mathematical background had not prepared him for the rigour of university mathematics and insufficient time was available for the support he required in this subject. He received some help from a neighbour who was studying Mathematics and Sports
Science; she explained percentages to him in a way that he was able to understand. He is aware that whilst he needed more help with basic mathematics there was not enough time available to address this problem.

There were several areas of difficulty that were experienced by Stuart. One was in statistics, where the delivery of material was too quick for him, but he stressed that this could also have been due to the fact that his statistical background was non-existent. He also encountered problems reading from statistical tables, saying, "I knew how to use them but all the numbers just joined together". Another area of difficulty he experienced was related to graphical interpretation where he said, "I needed to pencil in an extra line to establish where a particular point on a curve was located otherwise it just appeared to be floating about in thin air". It was this extra line that enabled Stuart to determine the co-ordinates of the point in question. The blue dotted line in Figure 14 shows an example of this.

![Graphical Representation Required by Stuart](image)

Figure 14: Graphical Representation Required by Stuart

Additionally, Stuart encountered problems with multi-stage operations. He explained, "If I tried to pick up a problem part way through, I just got lost. I needed to do stage 1 before I moved on to stage 2. It was impossible for me to go to, say, stage 6, without first having worked out all of steps 1-5". He elaborated on this by saying, "I had to learn each step individually and give each of these steps a label, once I had named each step I was OK so long as I worked through all the steps involved in the order which I'd labelled them". Stuart also mentioned that he doesn't see the need for "pernickety detail" and his mind often jumps over this, which sometimes results in him missing an important meaning or definition. When working with matrices he frequently transcribed numbers incorrectly unless he used a ruler to line up the row or column he was working
on. Additionally, he needed the matrix to be clearly labelled on more than one side; any small print on only one side of the matrix was inadequate for his needs. He described this small print as being "useless". He also expressed the view that it would have been beneficial to him if the matrix were to have been colour coded and drew an example of this. A reproduction of this is shown in Figure 15.

\[
\begin{array}{ccc|c}
  x & y & z \\
  \hline
  1 & 2 & 4 & 8 \\
  0 & 4 & 3 & 7 \\
  7 & 6 & 5 & 25 \\
\end{array}
\]

Figure 15: Matrix Representation Required by Stuart

When calculating the area under a graph, he needed a diagrammatic representation of the area in question. He needed to colour in the area he was calculating and place the \( y \)-axis on both sides of the graph or else he lost track when moving from the left hand side to the right hand side. He stressed that this style of presentation would have been useful to him. An example of this is shown in Figure 16.

Figure 16: Further Graphical Representation Required by Stuart

Stuart also finds the text he encounters in mathematics to be difficult to read, even if the presentation is in a sans serif font. His personal preference is Comic Sans. He uses this on his own computer, explaining that it appears slightly 3-dimensional, which makes it appear to rise out of the page. He perceives this font as being more like an image than a letter. He uses a cream background on his computer, which helps to reduce the glare that he experiences.
He does use coloured overlays, which help to reduce the glare from black print on a white background. However, he also added that they are not ideal; if he is using them to cover a piece of text, which he wishes to annotate, then they are not practical and furthermore he sometimes forgets to take them with him.

Stuart needs printed text to be double-spaced and also encounters difficulties discerning the difference between zero and the letter O, i.e., 0 and O, but does not have a problem with mathematical symbols. He also encounters problems with words, which have a similar spelling.

Stuart recounted that in an examination where the use of a box and whisker plot was required, he was able to answer the question by visualising his notes as this method is presented diagrammatically. An area of mathematics that he understood was graphical representation. He was able to explain quite clearly what the graph illustrated but whenever he had to perform a calculation it invariably went wrong. When asked if he could expand on this he said, "It was my manipulation of equations that went wrong".

Stuart seldom attended the tutorials for his mathematics modules. He explained, "I was so swamped with work that it depressed me even more when I attended them. I was struggling so much that I didn't know what to ask. I listened to the questions that were asked by other students but even the questions didn't mean much to me. It was better for me to attend my one-to-one sessions". He has attended the MLSC but found the time available with the lecturer on duty to be inadequate for his needs.

Stuart was agreeable for academic and academic-related staff to be notified of his dyslexia. He has found most of the staff to be helpful. He does, however, describe some staff as being rather bureaucratic about dyslexia.

His preferred style of delivery, in mathematical lectures, is one that includes, where possible, a diagrammatical representation of the material being covered. Ideally, at the start of a lecture, he would like to be given a printout from, for example, 'PowerPoint', so that he could write any additional notes on it. He would like handouts to be double-spaced, with an easy to read font (for him this is 'Comic Sans'), to use colour where
applicable and for them to be printed on a non-white background. Delivery of mathematical material is not in the format that Stuart would like.

Regarding the testing of modules, he finds multiple-choice questions difficult as the small difference between the given answers often confuses him. If, for example, two given answers were 1.001 and 1.01 then these would both look the same to him. The presentation of the options also has an impact on his ability to correctly identify the correct answer. For example, it is easier for him to relate to the number two million when it is presented as 2,000,000 rather than by 2 000 000. He explained that when he is looking at a long number he needs to break it down into thousands, hundreds, tens etc., and it is the commas that help him to do this. In written examinations Stuart frequently needs to turn to a new page in the answer booklet due to his large handwriting and he feels that this has contributed to the number of transcription errors he makes.

The use of mind maps assisted Stuart in the structure and recall of his work. He was initially introduced to them at primary school; he encountered brainstorming at secondary school and was given additional information on mind maps by a member of the ELSU, after he had been diagnosed as dyslexic. He has a mind-mapping programme on his computer but prefers to draw them for himself, saying, “I can break down procedures in exactly the way I want them, it is the building up of a diagram that helps me to recall the process in an examination”.

He describes the support he received from a member of the MLSC as being most beneficial in the areas related to the understanding of timetables and organisation rather than the actual mathematics he was encountering. The support he received from a member of the ELSU helped him to cope with being dyslexic and also helped him to analyse material he was reading.

Stuart concluded by saying that it came as a slight relief to discover that he was dyslexic and thereby there was a reason for the difficulties that he had been encountering. He is now extremely interested in the ways in which dyslexia manifests itself and the possible causes of dyslexia. He adds that he has found out a lot about the subject from friends who are teachers and, in particular, from a friend who had taught at a dyslexic school.
Stuart subsequently graduated with a Second Class Honours, Lower Division classification.

7.3.2 Report from the English Language Study Unit

Stuart is a nice charming chap, very chatty with good verbal communication skills. He had worked in an airline for a few years and thought that he knew the subject of Transport Management. He is a confident person and had had experience of managing people. At the stage when he came for screening he had been thinking about dropping out. The next time he visited the ELSU he was again thinking about dropping out due to all the problems he had. I wondered if a lecturer had told Stuart that he was not up to doing a degree course but it transpired that Stuart’s father had told him that he was getting ideas above his station. Stuart was given a lot of help at support sessions but failed to put it into practice. The problems appeared to be that he didn’t take on board what he was told and that he wouldn’t listen. Stuart would ask for help, and suggestions would be made to him, but he would then give reasons as to why the suggestions were no use and ignore them totally. Stuart has no idea of time management or time itself and always believed that he was right.

7.3.3 Report from the Mathematics Learning Support Centre

Stuart has huge problems; he is both dyslexic and dyspraxic and was struggling with everything. Stuart believed that he had developed his own coping strategies but unfortunately these did not work. He was unable to cope with timetables or airline schedules and a clock with moveable hands was used to help him in this area. Only a small part of each of his mathematics modules was concentrated on, as there were some areas that proved impossible to tackle. Stuart was able to do network analysis and optimisation after many support sessions. With graphical work, Stuart could understand an increase in the x-direction but not in the y-direction. He could only think in one dimension. If he was required to plot the co-ordinates (4, 2) he would mark a cross at 4 on the x-axis and another at 2 on the y-axis and then draw a line between the two crosses. Some topics, such as regression, were impossible to tackle; Stuart was unable
to plot or find the co-ordinates of points. Additionally, his reading skills were poor and it was necessary to highlight words for him. For example, once certain instructions for using SPSS had been highlighted Stuart was then able to follow them. Stuart did not listen to suggestions that were made to him, he didn’t use them, he just went away and did his own thing - he always thought he knew better. Fortunately, Stuart’s mathematics modules contained a lot of coursework.

7.3.4 Report from the Educational Psychologist

The EP’s report showed that Stuart has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 95. It describes Stuart as having relative strengths in verbal and non-verbal reasoning, and in verbal expressive skills. His relative weaknesses are in processing and organisation of visual information (visual working memory) and auditory working memory. The report grouped Stuart’s results into four cluster groups (see Table 15) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>73rd</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>18th</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>32nd</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>8th</td>
</tr>
</tbody>
</table>

Table 15: Stuart’s Cluster Group Scores from the Educational Psychologist

As can be seen, Stuart’s working-memory index, perceptual organisation index and processing speed index are extremely low when compared to his verbal comprehension index. The problems described by Stuart with multi-stage operations and sequencing are related to his low working memory index and low perceptual organisation index respectively. His reading difficulties referred to by a member of the MLSC are in accord with his low processing speed index.
The report recommended that Stuart be given individual specialist support for two hours per week, 25% additional time for timed assessments and examinations, additional time to complete written coursework and a recording device.

7.4 Case Study 4: Alan

Alan, an undergraduate in the Civil Engineering Department, was diagnosed as dyslexic during the final year of his MEng course. The following section includes all the information that was recorded during one interview, which Alan verified as being correct.

7.4.1 Interview with Alan

Alan entered university with three GCE A Levels: Chemistry and Mathematics at grade B and Biology at grade C. Alan explained that whilst he had never achieved the examination grades that he expected and was aware that he had co-ordination problems he had not considered that he might be dyslexic. It was the combination of his younger brother being diagnosed as dyslexic whilst at school, his poor marks on a CAA and some poor third year examination results that prompted him to make an appointment at the ELSU.

Alan explained that in addition to getting lost around the university campus another area in which he experiences difficulty is that of time, which results in him often turning up at the wrong time for lectures. He has also encountered difficulty in writing quickly enough to take down lecture notes. However, he does have up-to-date notes as he copies them from a friend who has very neat handwriting. As a result of being diagnosed as dyslexic he has been provided with a laptop computer, printer and scanner, and also has his photocopying paid for. However, he was not entitled to software for the computer as he is in the final year of his studies. In examinations he is now allowed extra time and the use of a computer. Alan feels that the help he has received has been adequate. With reference to the support that he has received, he said, "DANS were very good, but my council [LEA] were useless, it took them ages to respond".
When Alan was asked if there were any areas of mathematics that he understood but for which he frequently failed to obtain the correct answers, without hesitation he mentioned statistics, saying, “I understand it but never get the right answers”. In GCE A Level Mathematics he obtained grade A results for his three pure and two mechanics modules but a grade D for his statistics module. He explained that this is an area that has remained extremely problematic for him during his undergraduate studies.

He described the speed of mathematics lectures as rather fast but added, “This is OK as they are quite detailed”. He is unable to take down all the information but has found his mathematics lecturer to be helpful and, as mentioned earlier, he copies notes from a friend. Alan described the mathematics tutorials as “rubbish”; he expanded on this by explaining, “They’re frequently taken by PhD students who are often not in touch with the methods used by the lecturer and unable to explain the topic clearly”.

Alan has not visited the MLSC to obtain help as, apart from his difficulty with note taking, the main problem he encountered was with statistics, where the issue was his inability to produce correct answers rather than his lack of understanding of the topic or of what was being asked.

He finds it difficult to raise the subject of his dyslexia and told only his Head of Department. He did not inform his dissertation tutor but agreed that a member of the ELSU could notify his department.

His preferred style of lecture delivery is diagrammatic with bullet points. He does not like theoretical representation or computer-based learning. He also needs a clear detailed example of each mathematical method, explanation of where it will be used and where it fits into the mathematics he has already encountered. The styles of delivery that he has encountered in mathematics have involved too much writing, which has proved difficult for him. He would prefer to be given a printed sheet, containing only bullet points or the main equations being used, with plenty of space available so that he could then add more detailed information.

Methods of mathematical testing that have proved problematic for Alan are CAA and multiple-choice tests. He described a computer test saying, “I did the test, knew all the
answers and submitted it. I only got 45%. This was one of the reasons why I decided to see if I was dyslexic. I found out afterwards that I’d missed some of the instructions. I still feel that it was badly worded though”. He continued, “I always get rubbish marks on multi-choice papers too”.

Alan uses mind maps, which he draws himself, and also used flow charts to help him collect together ideas for his dissertation.

Alan subsequently graduated with a Second Class Honours, Upper Division classification.

### 7.4.2 Report from the English Language Study Unit

It was a combination of Alan’s brother being identified as dyslexic and Alan believing that he wasn’t doing himself justice (during his third year he had to re-sit two examinations) that made him decide to visit the ELSU. Alan has co-ordination problems and is unable to ice skate, roller skate or skateboard and was 13 years old before he could ride a bicycle. He also frequently trips up, falls over and mixes up left and right. For example, he is unsure as to which sides of a plate to place the knife and fork. Alan is unable to do things using a mirror, for example brushing his hair. He also encounters pain when writing.

### 7.4.3 Report from the Educational Psychologist

The EP’s report showed that Alan has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 122. It describes Alan as having relative strengths in verbal reasoning, reading and comprehension, 3-d information and spatial problem solving, long-term memory, working memory and mental arithmetic. His relative weaknesses are in grapho-motor fluency, visual discrimination and phonological awareness. The report grouped Alan’s results into four cluster groups (see Table 16) showing what percentile of the population he was in for each cluster group.
Table 16: Alan's Cluster Group Scores from the Educational Psychologist

As can be seen, Alan's processing speed index is extremely low compared to the other areas. Alan referred to his slow handwriting speed and his failure to read some of the instructions given in CAA, both of which are linked to a low processing speed index.

The report recommended that Alan be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, and computing equipment.

7.5 Case Study 5: Daniel

Daniel has completed a Foundation Course and is in his first year reading for a BEng degree in the IPTME. He was diagnosed as dyslexic when he was eight years old. The following section includes information that was recorded during one interview, which Daniel verified as being correct.

7.5.1 Interview with Daniel

Daniel's parents suspected that he and his brother might be dyslexic. He was, at the age of eight, diagnosed as dyslexic. Whilst at secondary school he received extra help with spelling, essay writing and structure until he was 16 years old. His mother also paid for him to attend additional spelling classes. During A Levels he received extra support with mathematics from his school. He entered university with three GCE A Levels: Biology and Physics at grade C and Mathematics at grade D.

Daniel has encountered difficulties that have impeded his progress whilst at university. These have been related to his poor organisational skills, which have led to him missing
some lectures. He expanded on this saying, “I need to write everything down else I forget it and I don’t like people to know I forget things. The timetable is a problem when some lectures only run for certain weeks and that’s when I’ve missed lectures”.

Daniel has a complete set of lecture notes this year, which he has taken himself. During his foundation year he was unable to keep pace with the material delivered in lectures, he spent time deciding what to write down and consequently his notes were incomplete. He explained, “Now I just write down everything I can and read through it after the lecture”. Through the DSA he receives one-to-one mathematics support for one hour per week from a member of the MLSC, which he finds very helpful. He also received a computer and uses ‘Dragon’ (speaking software) that was supplied with it. Daniel also receives an extra time allowance in examinations but has, so far, not needed to use it.

Daniel has not experienced any particular difficulty with the mathematics he has encountered and expanded on this by saying, “I have initial difficulties with all new material”. He has obtained incorrect answers to mathematics that he understands. This has occurred when he has become familiar with a particular method and has then been shown an alternative one; consequently he then gets the two methods muddled up. He found that there was insufficient time in the tutorials to address his difficulties. He has used the MLSC as a place to work and to obtain help but found the support in the MLSC to be inadequate for his needs. He described the lecturers on duty as not being on the same level as him and furthermore they were not able to spend a sufficient amount of time with him. Daniel recounted that one lecturer had said, “Do you mean to say you can’t do this”, He continued, “As a result of this I was too scared to say I don’t understand, I didn’t want to be made to feel stupid”. He is willing for academic and academic-related staff to be notified that he is dyslexic but does not want to notify staff personally.

He prefers mathematical material to be delivered via a blackboard in an uncluttered format with a simple layout containing a mixture of text and diagrams; he finds dense blocks of descriptive writing particularly difficult and would like to be given handouts containing bullet points, which he could then annotate. He described the Helping Engineers Learn Mathematics (HELM) workbooks as being excellent, adding, “They’re really well laid out it would be good if there was something like this for all the
modules" (see http://www.lboro.ac.uk/research/helm/) He finds the delivery of mathematical material to be fast and not in the format he would like. What he would like is any important equations to be written on one side of the blackboard and left there for the duration of the lecture with the remainder of the board used for worked examples. He also finds it difficult to maintain his attention during a 50-minute session that just involves the lecturer talking. He described an ergonomics module as being ideal for him; the lecturer interacted with the students and this held his interest.

Daniel finds long exams difficult as he loses concentration whereas in-class tests, CAA and multiple-choice are not a problem. He uses a blue overlay, which helps to reduce glare when he is reading and doesn't use mind maps.

Daniel failed several modules and is now re-sitting the first year of his course.

7.5.2 Report from the Mathematics Learning Support Centre

Daniel has known about his dyslexia since childhood, and has developed good coping strategies. He is methodical in his approach to both work and life in general and with this approach he is able to minimise the effects of his dyslexia. Nevertheless, Daniel is very forgetful over times and appointments, however, mathematically he is reasonably competent once the material is in his long-term memory. His basic mathematical level is sound but he struggles with higher-level skills. He is extremely industrious and organised, bringing his problems and queries to each session. He is also very specific in his questions, for example, wanting to know exactly how the lecturer has got from one line to another. Daniel is not particularly stressed or anxious as long as he is keeping up with his work. His revision strategy is to work through lots of past papers.

7.5.3 Report from the Educational Psychologist

The EP's report showed that Daniel has an IQ on the Wechsler Adult Intelligence Scale - Third Edition (WAIS-III) of 128, which is greater than 97% of individuals of his age. It describes Daniel as having relative strengths in fluid intelligence (culture free
reasoning), perceptual organisation and spatial ability. His relative weaknesses are in sequential ability, acquired knowledge and working memory. The report grouped Daniel's results into four cluster groups (see Table 17) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>86th</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>37th</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>99th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>82nd</td>
</tr>
</tbody>
</table>

Table 17: Daniel's Cluster Group Scores from the Educational Psychologist

As can be seen, Daniel's working memory index is extremely low compared to the other three areas. A member of the MLSC described Daniel as very forgetful and Daniel himself explained that he needed to write down everything, as he was forgetful. Daniel also mentioned that his limited concentration span caused problems in lengthy examinations. These shortcomings are linked to his low working memory index.

The report recommended that Daniel be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, and computing equipment with appropriate software.

7.6 Case Study 6: Chris

Chris is reading for a MEng in the Electronic and Electrical Engineering Department and is in his second year of study. He was diagnosed as dyslexic whilst studying for his GCE A Levels. The following section includes information that was recorded during one interview, which Chris verified as being correct.

7.6.1 Interview with Chris

Chris was born in the UK but moved abroad when he was nine years old. He attended an international school until the age of 12 and then entered a boarding school in the UK.
It was Chris’s mathematics teacher who suspected that he might be dyslexic. During his A Level studies Chris was diagnosed as being dyslexic and subsequently received one hour of tutorial support per week. This support included revision techniques, writing skills and help with memory recall. He obtained three GCE A Levels: French at grade B, Physics at grade C and Mathematics at grade D.

Chris has encountered difficulties that have impeded his progress whilst at university. He can learn material but two weeks later he is unable to remember it. It takes him a long time to get through the volume of work. He also has difficulty understanding his lecture notes and he spends a long time trying to work out what some lecturers are doing. When asked to explain this he said, “They [the lecturers] assume things are obvious but they’re not to me”.

Chris has a complete set of lecture notes, which he has taken himself. He also spends time writing out model answers to help him with his revision and always prints any additional material from the VLE. However, he often misses what a lecturer is saying as he is still busy taking down the notes. He finds it is the amount of material, rather than the speed of delivery, that is the greatest problem for him. He is not classed as a home student and, therefore, has not been assessed by an EP. He receives extra time in examinations and one-to-one tutorial support with mathematics. As an international student, he is not eligible for a computer and feels that this would be helpful to him.

The particular difficulties that Chris has experienced with mathematics are the rearrangement and recall of formulae, and algebra in general. He does experience some visual disturbance when working with rows and columns of figures but describes this as “minimal”. Nevertheless, it has resulted, on occasion, in him obtaining incorrect answers to material that he understands. Chris attends both the timetabled tutorials and his one-to-one support sessions for mathematics and added “I have visited the MLSC loads as I really want to keep on top of everything, but when the Centre’s busy it’s hard to have enough time with the lecturer for it to be much help”. He has found the tutorials to be good but the one-to-one mathematics support to be most helpful.

Chris finds it easiest to work with a mixture of text based and diagrammatic representation. He prefers the lecturer to handwrite material on the blackboard or OHP,
which he can then copy down exactly as it is written. For his mathematics modules the material is delivered in the format he likes and he added, "The lecturer does lots of fully-worked examples which is really helpful".

Chris has not encountered any forms of testing that are particularly difficult but added "I feel that the computer tests are pretty cruel, they're totally unforgiving". He does not use mind maps or a coloured overlay.

Chris is now in the third year of his degree programme.

7.6.2 Report from the Mathematics Learning Support Centre

Chris is very mathematically able but lacking in confidence. He has neat and well-structured notes. The main problem he encounters is that of making copying errors from line to line when working through questions.

7.7 Case Study 7: Anthony

Anthony is reading for a BEng in Mechanical Engineering and is in the first year of his course. He was diagnosed as dyslexic when he was seven years old. The following section includes information that was recorded during one interview, which Anthony verified as being correct.

7.7.1 Interview with Anthony

Anthony's mother was unhappy with a teacher reporting that her son was messing about in class, was lazy and not trying. She did not believe that Anthony was not trying and suspected that he might be dyslexic. He was diagnosed as being dyslexic when he was seven years old. Subsequently he was given extra help at school and at GCSE Level he was awarded extra time in examinations and the use of a computer. Anthony obtained
four GCE A Levels: Information Technology (IT) at grade A, Physics at grade B and both History and Mathematics at grade C.

He has encountered difficulties that have impeded his progress whilst at university and these have been related to his short attention span:

I have a problem in lectures if I’m not keeping up with what’s happening and outside of lectures I get easily distracted. I find it difficult to take notes and listen to what the lecturer’s saying, my writing’s not neat enough and I make lots of mistakes such as writing $xa$ instead of $x^a$.

Anthony has a complete set of notes and now has a note taker, however, he made the point that whilst the notes are extremely neat they are often not dated or labelled and he has encountered problems distinguishing between the thermo fluids and the thermodynamics notes. He now uses a mixture of his own notes and those provided by his note taker for revision. Anthony also receives one-to-one mathematics support and receives extra time in examinations, which he uses for proof reading his work. He has been provided with a scanner, read and write software and mind mapping software. He occasionally uses the read and write software and added, “The spell checker is excellent but at the moment I’m doing the wrong sort of work to use it”. He finds the mathematics support to be excellent but points out that, “This form of one-to-one support would also be helpful with mechanics and fluids modules for which there is no help”.

Particular difficulties encountered by Anthony are related to determining what a question is actually asking. He has difficulty with algebra and commented, “I also make classic dyslexic mistakes with notation and number work such as $3+3 = 9$ and $3\times3 = 6$”. He also feels that there is a big disparity between his mathematical knowledge and understanding when compared to those students who have taken GCE A Level Further Mathematics. He experiences some visual disturbance with black text on a white background, which has, on occasions, resulted in him obtaining incorrect answers to material he understands, such as questions involving matrices. During the first semester he attended his mathematics tutorials but was unable to obtain sufficient help, as the group was too large. Also, during the first semester he frequently attended the MLSC
and found the help he received to vary considerably, being dependent on the lecturer on duty. He recalled one instance, "I asked the lecturer on duty a question and was told that it [what I asked] was simple, which wasn't very helpful". During the second semester he has used the MLSC less and not attended mathematics tutorials as the one-to-one support is addressing most of his problems. Anthony is willing for academic and academic-related staff to be notified of his dyslexia.

He prefers mathematical material to be delivered via a blackboard or OP, but not by using pre-prepared transparencies. He likes a diagrammatic approach to be used where possible and worked examples, with all the steps explained, to be given by the lecturer. He also likes to receive handouts after the lecture but not to be used in conjunction with it saying, "They are useful if they are not too cluttered and reasonably worded". He finds bullet point presentation of material unhelpful as he finds it difficult to link what is being said to the bullet points. The delivery of mathematical material is in the format that Anthony likes, "The lecturer writes on an OP, explains what he is doing, uses colour to highlight equations and if he makes a mistake he clearly corrects it". He finds the HELM booklets confusing and difficult to use.

Anthony finds traditional examinations difficult but prefers them to CAA or multiple-choice tests:

I have to try to identify from the words what's required, I mean what's actually needed is hidden in the question. I have to read everything several times and then lose my concentration but I do prefer a written examination to CAA or multiple-choice where the language is clearer but then it's so easy to make transcription errors or lose confidence in the answers you get when presented with several similar ones.

He doesn't use a coloured overlay but does draw himself mind maps; he is now learning to use the mind mapping software but feels that the greatest benefit comes from hand drawing them.

Anthony is now in the second year of his degree programme.
7.7.2 Report from the Mathematics Learning Support Centre

Anthony has difficulty with decoding text and has to re-read sections many times. He struggles with questions that are embedded in text. His reading is slow and he is very prone to making transcription errors between lines and between media (for example from calculator to paper). He finds the HELM booklets very difficult to follow and prefers his own notes and those from his note taker, which have been taken in the lectures. He needs consistency in approach and finds any irregularity difficult.

7.7.3 Report from the Educational Psychologist

The EP gave only a summary report as Anthony had a full report from when he was at school. The report showed that Anthony has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 114. The report recommended that he be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, computing equipment with appropriate software and a note taker.

7.8 Case Study 8: James

James is reading for a MEng in Computer Network and Internet Engineering and is in the second year of his course. He was diagnosed as dyslexic when he was 14 years old. The following section includes information that was recorded during one interview, which James verified as being correct.

7.8.1 Interview with James

It was suggested by a teacher at James’ lower school that he might be dyslexic. James said, “I was upset by the suggestion, I didn’t want to appear different to the rest of the class and consequently nothing was done as I didn’t want to proceed with formal testing”. His mother paid for him to receive private tuition in English. It was during the
year preceding his GCSE examinations that James decided to undergo formal testing for dyslexia and as a result of being diagnosed as dyslexic he received help from the school with English and spelling, and was awarded 25% extra time in examinations. James found this extra time to be very helpful both at GCSE and GCE A Level. He entered university with three GCE A Levels: IT at grade A, Computing at grade B and Mathematics at grade C.

James has encountered difficulties that have impeded his progress whilst at university. These have been related to his poor short-term memory whereby he forgets material he has recently encountered. James also explained, “I feel like a computer with only so much memory to fill up and it’s constantly being overloaded”.

James does have a complete set of lecture notes for his mathematics modules, which are a combination of those that have been taken by him and those that he has printed from the VLE. He was offered a note taker but declined this as much of the material is available as handouts or is on the VLE. He finds the speed of delivery in mathematics to be quite quick but appreciates that the lecturer has a lot of material to deliver. He has found there to be a great difference between school and university saying, “At A Level we spent a long time on each topic but at university there are loads of topics in each module”. He also added “without the handouts I would have had a big problem with note taking as I can’t write quickly enough to take it all down and miss what the lecturer is saying”. Through funding from the DSA he receives one-to-one mathematics support for one hour per week from a member of the MLSC, which he finds very helpful. He has also been given a recording device but has not used it as the modules he is taking do not lend themselves to this sort of equipment. He receives 25% extra time in examinations and has been given a laptop computer plus software. James has used the ‘brainstorming’ software but not the read and write speech package saying, “It is not really suitable for technical subjects”.

James has experienced particular difficulty with predominantly text-based material such as the descriptive narrative encountered in statistics and with multi-stage problems such as Fourier series and partial differential equations. He frequently obtains incorrect answers to material that he understands through making transcription errors such as missing out minus signs or by making computational mistakes and is aware that he
should use his calculator more often when undertaking numerical work. James attends his mathematics tutorials and says, "They are really good, the people at Loughborough are really helpful". He has visited the MLSC frequently and found it to be very useful but added, "Some of the staff are just so clever that they can’t relate to the students’ problems; they’re just not in touch with what we know". James is willing for academic and academic-related staff to be notified that he is dyslexic.

He prefers mathematical material to be delivered by the lecturer actually writing it on a blackboard or OP saying, "In this way the lecturer says what he is doing and goes at a slower speed than when using pre-prepared material". For more wordy subjects he would like a handout containing bullet points, which he could then annotate. James would also like a diagrammatic approach to be used wherever possible and material to be placed on the VLE prior to, rather than after, lectures. He finds the delivery of mathematical material to be in the format he likes albeit rather too quick.

James finds written examinations difficult and stressful and prefers the CAA testing. He explains that for this style of examination, "I only have to revise one particular topic, which means that I don’t get overloaded with material, I seem to do well in these as I don’t get confused with similar methods and where they are used". He doesn’t use a coloured overlay and added, "I’m pretty sceptical about how much use they actually are”. James uses mind maps for mathematics and more frequently for structuring written work; usually drawing them himself rather than using the provided software. James is now in the third year of his course.

7.8.2 Report from the Mathematics Learning Support Centre

James is mathematically able, with no discernable problems. However, he has a tendency to rush and is always trying to find a shortcut rather than taking the time to truly understand a topic/ technique. His notes are messy and unstructured.
7.8.3 Report from the Educational Psychologist

The EP's report showed that James has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 106, which is greater than 66% of individuals of his age. It describes James as having relative strengths in verbal comprehension and perceptual organisation. His relative weaknesses are in phonological processing, sequential ability, processing speed and working memory. The report grouped James' results into four cluster groups (see Table 18) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>77th</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>47th</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>77th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>14th</td>
</tr>
</tbody>
</table>

Table 18: James' Cluster Group Scores from the Educational Psychologist

As can be seen, James' working memory index and processing speed index are extremely low compared to the other two areas. James referred to his memory overload, likening it to a computer with limited memory and also described his difficulties with descriptive narrative. These difficulties are directly related to these two low index scores.

The report recommended that James be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, a note taker and computing equipment with appropriate software.

7.9 Case Study 9: Jack

Jack is reading for a BEng in Civil Engineering and is in the second year of his course. He was diagnosed as dyslexic when he was eight years old. The following section includes information that was recorded during one interview, which Jack verified as being correct.
Jack recognised at primary school that other children in his class were progressing faster than he was. He said, "It didn't matter how hard I tried I still made loads of mistakes". His parents, who were professional people, were concerned that their child who appeared to be intelligent was doing so poorly at school. They visited the school and suggested that Jack might be dyslexic but the school did not think that this was the case. Jack was then taken by his parents to a private institute and diagnosed as dyslexic. He subsequently received some help from his junior school. He did not go to his local comprehensive school as his parents had determined that a school a few miles away had, 'An Accelerated Learning Department for Dyslexia'. His parents also paid for a private tutor to assist him. Regarding his secondary education he said, "I was given a lot of support and encouragement, I always tried, always attended, and they really helped me. By the time I was 14 I was up to speed and at the same level as my peers in everything except reading and writing and I still mix up the letters b and d". Jack was very upset when he was predicted to obtain only six GCSE's at grades A - C. This prediction was not very accurate as he obtained four A*'s, four A's, three B's and one C. Jack entered university with three GCE A Levels: Physics and Technology at grade B and Mathematics at grade C.

He has encountered many difficulties that have impeded his progress whilst at university. These have mainly been related to the drastic change in lifestyle. Jack explained:

I just couldn’t find my feet, at school I was a big fish in a small tank but at uni I was a small fish in a big tank. I didn’t know where to go, I kept getting lost, I found the campus daunting and on top of it all was the huge change to independent living. I got confused with phone numbers and addresses but I eventually found DANS. Then I missed my first appointment with the Educational Psychologist because I hadn't written it on my timetable. I was so distraught at first that my mum phoned up uni. It was such a change from A Level when we worked through the textbook sequentially. There was so much information in lectures, my handouts and notes were in a total mess. My planning skills are useless and I'd got the notes from different modules all jumbled up, especially in modules where there was an overlap...
of content. I often miss what the lecturer is saying because I’m still copying from the blackboard.

He now has an up to date set of lecture notes for all his modules yet this was not the case in his first year. Jack explained, “I was not exactly brilliant at getting lecture notes, at first I didn’t write everything down except for maths where I made loads of transcription errors. In other subjects I didn’t annotate handouts and got them mixed up or lost them”. Jack came to university with his own laptop and through the DSA he has received a scanner and software including a voice ‘speak back’ package (which he finds very useful) and ‘Inspiration’. He has also received a recorder and said, “It’s useful in lectures with a lot of talking but it’s not much use for subjects like maths”. He receives extra time in examinations, which he finds particularly useful in modules that entail a lot of reading or writing. Jack described the speed of delivery in mathematics lectures as “Mach I” but added, “It’s fast but interesting, the lecturer shows us lots of little tricks for doing things, I don’t always get all the material written down so I always go through my notes with a friend after the lecture”.

There are particular areas of mathematics that Jack has encountered difficulty with. He experiences visual disturbance and has problems with matrices, systems of equations and using statistics tables. Jack found partial differentiation confusing and often got lost when undertaking multi-stage mathematical operations. Extracting the required information from lengthy text, such as encountered in statistics, is difficult for him. He finds some units of measurement, mathematical notation, symbols and formulae bewildering. Jack gave some examples, “If the lecturer writes or says \( \bar{x} \) I always write the word mean, and for cubic measurement I don’t write the power 3, I actually write cubic”. He also has problems trying to ascertain where a new topic fits into the mathematics he has already encountered and says “I sort of need to see everything, it’s like being given a map of a county, what I need is a map of the whole country”. When asked if there were any areas of mathematics that he understood but for which he frequently obtained incorrect answers he immediately responded, “matrices, row operations, using pivots and statistics”. Jack finds the mathematics tutorials to be excellent, saying, “The postgrads seem to be more in touch with students’ level of understanding and knowledge than the lecturers, the only problem is they [the tutorials] should be longer than 50 minutes”. He has also used the MLSC as a place to work on
tutorial sheets and found it to be, “An excellent working environment with the added bonus of help being available if you get stuck”. He is willing for academic and academic-related staff to be informed that he is dyslexic and he mentioned that he was dyslexic to staff in the Civil Engineering General Office.

Jack prefers a diagrammatic delivery wherever possible, which he then colour codes, with material being written on the blackboard or OP. His mathematics modules are delivered in a way that he can work with although the pace, like all his other modules, is too fast.

Jack finds CAA to be particularly difficult. He explained, “In written examinations I write out every step of what I’m doing so if I make a mistake the lecturer can see where I’ve gone wrong, but in the computer assessments if I’ve put the decimal point in the wrong place or made a transcription error I’ll just get zero”. Jack has not had one-to-one mathematics support or visited the ELSU for help but realises that he will need assistance with any tasks that require lengthy written work to be undertaken. He recalls that a yellow overlay was found to be helpful for him but he did not obtain one and has no intention of using one. He has used mind maps, which he draws himself, for mathematics and coursework. In addition he makes summary notes of his lecture notes and uses these in conjunction with his mind maps for revision.

Jack is now in the final year of his course.

7.9.2 Report from the Author of this Thesis

Jack was not receiving support from the ELSU or the MLSC but was aware that it is available if he should need it. The author of this thesis was responsible for a mathematics tutorial during Semester two of Jack’s second year, which he attended regularly. Due to his regular attendance, and the small number of students who actually attended, it was possible to work with him for quite long periods of time and observe where his difficulties lay.
Jack is a lively talkative and friendly young man and is open about his dyslexia and the problems he has. It was observed that he made frequent transcription errors from line to line and from calculator to paper. His writing is untidy and he has a tendency to rush through his work, which often results in him not reading questions thoroughly. His mathematical ability and understanding of the mathematics he encountered was good, nevertheless it was difficult for him to recall a method he had encountered previously but not used for some time. His transcription errors were most apparent in work with matrices and systems of equations for which he rarely obtained the correct answer.

7.9.3 Report from the Educational Psychologist

The EP’s report showed that Jack has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 103. It describes Jack as having relative strengths in interpreting abstract visual information and visualisation during problem solving. His relative weaknesses are in word decoding. The report grouped Jack’s results into four cluster groups (see Table 19) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>58th</td>
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<tr>
<td>Working Memory Index</td>
<td>37th</td>
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<tr>
<td>Perceptual Organization Index</td>
<td>86th</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>14th</td>
</tr>
</tbody>
</table>

Table 19: Jack’s Cluster Group Score from the Educational Psychologist

As can be seen, Jack’s working memory index and processing speed index are extremely low compared to the other two areas. His forgetfulness, difficulties with multi-stage operations and poor reading and writing skills are in accord with these low scores.

The report recommended that Jack be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, computing equipment with appropriate software and a recording device.
7.10 Case Study 10: Bob

Bob is reading for a BEng in Applied Design and is in the first year of his course having successfully completed a Science and Engineering Foundation Studies course at Loughborough University. He was diagnosed as dyslexic when he was 11 years old. The following section includes information that was recorded during one interview, which Bob verified as being correct.

7.10.1 Interview with Bob

Bob received extra reading lessons at primary school from six years of age and by the time he was seven years old he was found to be behind in English and arithmetic, and was experiencing particular difficulties with his times tables. At this stage of his education Bob felt that he was not as good as everyone else in his class. His parents, who had been helping him with his reading, believed that he was dyslexic and approached his school. Bob was subsequently diagnosed as dyslexic with particularly weak skills in processing speed being identified. He received support throughout his secondary education. Bob entered university with two GCE A Levels: Design at grade B and Geography at grade D. He failed his Physics A Level.

He has encountered problems with algebra that have impeded his progress whilst at university and most of his problems have been of a mathematical nature, which he believes is due to his non A Level background in this subject. He also forgets appointments and adds, “I often set off somewhere and then forget where I’m going and who I’m supposed to be meeting but I can remember phone numbers”.

Bob has a complete set of lecture notes that he has written himself. However, he describes the speed of delivery in mathematics lectures as, “Too fast and there’s too much too soon”. Through funding from the DSA he receives one-to-one mathematics support, which he has found extremely helpful. He receives 25% extra time in examinations and should be receiving a computer if his LEA agrees to fund this. Bob feels that once he has a computer the help he is receiving will be adequate.
One particular areas of mathematics that has proved problematic to Bob is algebraic manipulation. He also has problems with differentiation and integration, where he often becomes confused between the title and the task, i.e., integrating a function instead of differentiating it. He also encounters difficulty in distinguishing between the title and the task when confronted with Arithmetic and Geometric progressions. He finds multi-stage operation to be particularly difficult, saying, “I forget where I am and where I’m going”. Bob has obtained incorrect answers to material that he understands such as solving systems of equations. When asked why this was he explained, “Sometimes when I’m reading, the letters just fade out, I wear blue tinted glasses in exams or when I’m tired and this helps”. The tutorials are not able to address the difficulties that he encounters; he needs one-to-one support for a greater length of time than is available in them and now only attends his one-to-one support sessions. He has only used the MLSC once as he found the room to be too noisy and he was unable to concentrate. He is willing for academic and academic-related staff to be notified that he is dyslexic and is grateful to the lecturers who have provided him with notes.

He prefers to be given handouts, which he can then annotate, as long as they are well spaced out and do not contain dense blocks of text, which he then has to read several times to obtain the meaning. It is very helpful to him if diagrams and bullet points are included wherever possible. He does not like pre-prepared transparencies to be used. If these are used he finds that the lecturer goes even faster and says, “I start to panic that they’ll take it off before I’ve written it all down”. The delivery of mathematical material is not in the format he would like. Bob expanded on this by saying, “The delivery is far too quick, there aren’t any handouts and it takes me all my time to copy it down, there’s too much to take in, I totally miss everything the lecturer is saying and there isn’t enough explanation about how topics fit together”.

Bob finds multi-choice examinations and CAA to be particularly difficult. He finds the similar answers to be confusing and added, “The visual disturbance I have makes it all too easy for me to fill in the wrong box. Written examinations depend on whether I’m having a good day or a bad day, if it’s a bad day I may start to panic and that blocks my mind”. Bob uses coloured glasses in preference to an overlay. He was given information on mind maps whilst he was at school and a member of the DANS has also suggested that he use them but he prefers to use a mixture of bullet points and diagrams.
Bob is now in the second year of his course.

7.10.2  Report from the Mathematics Learning Support Centre

Bob was diagnosed as dyslexic early in his education. He has very slow processing speed, poor sequencing and weak working memory. He needs to repeat basic mathematical processes many times to assimilate new concepts, particularly algebraic ones. His reading is slow and he needs to re-read sections repeatedly to process the information. He struggles with revision techniques and in examinations he uses all of his extra time but still often fails to finish the examination paper.

7.10.3  Report from the Educational Psychologist

The EP’s report showed that Bob has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 112. It describes Bob as having relative strengths in verbal comprehension and conceptualisation, perceptual organisation and spatial ability, crystallised intelligence (culturally acquired abilities) and fluid intelligence (culture free reasoning). His relative weaknesses are in phonological processing, sequential ability, processing speed and working memory. The report grouped Bob’s results into four cluster groups (see Table 20) showing what percentile of the population he was in for each cluster group.

<table>
<thead>
<tr>
<th>Cluster Group</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Comprehension Index</td>
<td>82&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Working Memory Index</td>
<td>30&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Perceptual Organization Index</td>
<td>88&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>58&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 20: Bob’s Cluster Group Scores from the Educational Psychologist

As can be seen, Bob’s working memory index and processing speed index are extremely low compared to the other two areas. Bob referred to himself as being forgetful and having difficulties with multi-stage mathematical operations and a
member of the MLSC emphasised that to take on board new concepts he needs to repeat mathematical processes many times. These difficulties are in accord with his low working memory index. Linked to his low processing speed index are his slow reading skills and his need to re-read material several times to process the information.

The report recommended that Bob be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations and computing equipment with appropriate software.

7.11 Case Study 11: Joseph

Joseph is reading for a MEng in Civil Engineering and is in his final year. He was diagnosed as dyslexic during the fourth year of his course. The following section includes information that was recorded during one interview, which Joseph verified as being correct.

7.11.1 Interview with Joseph

Joseph explained that he experienced problems with reading and writing from a young age but was not tested for dyslexia during his school years. His mother paid for extra tuition in reading and writing for him from the age of eight to 19. He entered university with three GCE A Levels: Art at grade A, Mathematics at grade B and Business Studies at grade D. Joseph explained that he struggled during his first two years at university, but it was during his placement year that colleagues noticed his elementary mistakes with words and numbers and suggested that he might be dyslexic. On return to university he underwent dyslexia screening and was subsequently diagnosed as dyslexic.

He has encountered difficulties that have impeded his progress whilst at university. Joseph explained:
I need a bit of guidance and direction; it takes me a long time to get my head round new concepts. There was a lack of support from academic staff and I’ve had to rely on fellow students to help me. I would rather have received help from the academics who are paid to do it.

Joseph does have a complete set of lecture notes as he has a note-taker, which enables him to just sit and listen. Prior to being awarded a note-taker he did not have a complete set of notes and explained, “My notes were so poor and I was so unorganised, I used to photocopy my friend’s notes at the end of term. In my second year I started copying notes from a student in the year ahead of me so I had them in advance of the lectures”. He finds the speed of delivery in mathematics lectures to be too fast with the material being covered in insufficient depth. Through the DSA he receives two hours of one-to-one support per week. One hour with a member of the ELSU where he is given help with report writing and organisational skills; he described this person by saying, “She’s like a second mum”. The other hour per week is spent with a member of the MLSC. He has also been assigned a postgraduate student who is available to help him, however, Joseph says, “This isn’t much help as the postgrad has forgotten a lot of the stuff”. He receives extra time in examinations and has been provided with a computer with a selection of software. He finds the software for mind maps useful but not the read and write package, saying, “It’s a good idea in theory but in practice it doesn’t really work”.

Joseph encounters particular difficulty with statistics and the problem is compounded as he experiences some visual disturbance, which makes statistics tables difficult to use. He frequently obtains incorrect answers to solving systems of equations, a procedure he fully understands and makes mistakes copying figures from his calculator. He also explained, “My short-term memory is very poor, for example, if someone read out the number 8911 I could quite easily write it as 981”. The mathematics tutorials, which were very poorly attended, were able to address some of his difficulties but there was insufficient time available to work through everything he needed help with. He has used the MLSC but did not find that it offered the support he needed. He found it to be, in general, very busy with the lecturer on duty only able to spend a short period of time with him. Joseph is willing for academic and academic-related staff to be notified that he is dyslexic but finds it difficult to tell staff himself. He expanded on this by saying, “When I’ve mentioned that I’m dyslexic, they [staff] don’t seem to understand my
difficulties. I think they should be made more aware of dyslexia and the problems that dyslexic students encounter”.

He would like to be given handouts prior to the lecture with lots of space between the lines of text so that he could annotate them. He doesn’t like lecturers to use pre-prepared transparencies saying, “These seem to be flashed on and off the OHP really quickly”. It is best for him if the lecturer writes a worked example on the board or OHP and he can copy it onto a handout. He also experiences difficulty if lecturers have unclear handwriting. Joseph found the delivery of mathematics to be fast but manageable.

Multi-choice examinations pose the greatest difficulty to Joseph as the variety of answers confuses him and he may easily get mixed up with which question number he is working on, especially if he has left one question out to return to it later. He also said, “I would have hated to do the computer tests that are now in use, there are no method marks and with the amount of transcription errors I make I’m sure I would have got zero for every test”. Joseph does not use a coloured overlay. He has been using mind maps since he was diagnosed as dyslexic and finds they help him to understand and recall material; he draws them himself and also uses the computer package.

Joseph graduated with a Second Class Honours, Upper Division classification.

Joseph did not agree to the author of this thesis viewing his report from the EP.

7.11.2 Report from the Mathematics Learning Support Centre

Joseph has had a lot of difficulties. He was identified late – probably in Year 4 of his degree course. Coming to terms with his dyslexia has been difficult for him and he has struggled with most aspects of the Civil Engineering course, except the practical components. He was very successful on his work placement year and was offered a job, which I believe he has now started. He obtained a 2:1, which is very pleasing. His mathematics is weak and he needed support with a civil module on environmental engineering, which was very difficult. There was not any information on the VLE and the lecturer concerned was not very forthcoming in giving access to notes and solutions.
The notes he gave out were photocopies of textbook chapters with much irrelevant information and a few useful formulae if you could find them. Some solutions from the lecturer were eventually obtained and worked through with Joseph. Joseph has weak working memory and each week we needed to recap the material, in fact we covered the whole module several times. In the end he obtained a really good mark.

In Semester two Joseph expected to receive the same amount of information from another lecturer but this could not be justified as the module in question was not 'wordy' and adequate notes were provided. It was mostly work associated with matrices that Joseph struggled with. Another member of the MLSC also spent some time working with him on this topic.

7.12 Case Study 12: Lee

Lee is reading for a BEng in Civil Engineering and is in his first year, during which time he was diagnosed as dyslexic. The following section includes information that was recorded during one interview, which Lee verified as being correct.

7.12.1 Interview with Lee

During the second year of Lee's GCE A Levels his geography teacher noticed that he was spelling certain words in several different ways and suggested that he might be dyslexic. Lee also noticed that at this level he was struggling with mathematics more than the rest of his peer group. He said, "I needed everything to be explained thoroughly before I could understand it. I sort of needed the penny to drop or else I was rubbish at it". He entered university with four GCE A Levels: Geography at grade B, Mathematics at grade C, Physics at grade D and General Studies at grade E. It was while he was working in the MLSC that he saw the dyslexia checklist sheets and filled one in. He answered yes to about 75% of the questions and made an appointment with the appropriate member of staff in the MLSC. He was subsequently diagnosed as dyslexic.
Lee has encountered difficulties that have impeded his progress whilst at university. He described the pace of work as being much quicker than at school with the need for more independent reading and study. He experiences visual disturbance when reading and explained that he frequently finds himself reading the same line twice, is unable to make sense of what he is reading as he has missed out a line and has to re-read material to obtain an understanding of what he is reading. He also has problems where topics in different modules overlap saying, “Everything seems to merge into one thing if there are no clear boundaries between topics”.

He has a complete set of lecture notes that he has taken himself but finds the delivery of material in all his modules to be, “fast, everything is too fast”. Through the DSA he receives one-to-one mathematics support for one hour per week from a member of the MLSC, which he described as “brilliant”. He is to be provided with some software for his computer but has not yet received it. Lee receives extra time in examinations and stated “I feel that I shouldn’t be penalised for spelling, punctuation and grammar mistakes in assessment procedures”.

Lee has experienced particular difficulty with calculus and trigonometry, subjects he had not fully grasped at A Level. He explained that he can do the basics but the delivery of so many different methods in rapid succession has confused him. He frequently obtains incorrect answers to statistics questions saying, “I’m OK with statistics but it all goes wrong when I have to use the tables, I use two wooden rulers to isolate the row I need but even then I sometimes end up reading from the wrong column”. The mathematics tutorials were inadequate for his needs. Lee explained, “During my first semester I was so stressed, the work got on top of me and the postgrad student [taking tutorials] spoke poor English and said things like you should know this, so I just stopped going”. During the second semester he attended his one-to-one support session but not his tutorials. Lee has visited the MLSC but found the help he has received to be variable. Some lecturers on duty were able to see that he was lacking background knowledge but others were unable to see where he was struggling. Lee expanded on this, saying:

I got a rubbish mark on the diagnostic testing and one lecturer went through some questions with me, saw where I was having problems and gave me a booklet on
algebra, which was really helpful. On another occasion I was struggling with
differential equations but all the lecturer did was to do the next line of the question
for me, she couldn’t see that I needed to understand where the equations had come
from and what was happening. I went back several times until I found someone
who explained it from the beginning. It’s off-putting that every time you go [to the
MLSC] there’s someone different in there and they usually can’t spend much time
with you because it’s so busy.

He has not found the help he has received, other than that given in his one-to-one
sessions, to be adequate for his needs. He finds the lecturers to be, “Too far removed
from lower level maths. They just expect you to be able to sort it out for yourself, they
don’t explain the basics or the underlying maths you might need”. Lee is willing for
academic and academic-related staff to be notified that he is dyslexic.

Lee prefers material to be delivered using a mixture of diagrams, which really help him
to visualise the situation, or bullet points. He requires worked examples and explained,
“I need the lecturer to use words to explain what is happening and [I] also [need him] to
link symbols to operations”. He does not like using a computer to learn mathematics
and does not like the lecturer to use transparencies as, “These get removed from the
OHP too quickly”. He finds the delivery of his mathematical material to be satisfactory,
“It’s OK as he [the lecturer] writes on the OHP and this slows him down a bit”.

Multi-choice examinations pose a problem to Lee as he gets lost trying to determine
where he is and becomes confused with so many similar answers. Lee does not like the
use of CAA as there are no method marks and a transcription or rounding error will
result in him getting zero. He prefers coursework saying, “It takes me a long time but I
can generally get good marks for it and it represents real life. Like if you were at work
and had to solve a problem you’d be able to do it by using your notes or textbooks or
the Internet”. He does not feel that written examinations reflect his real ability. Lee was
offered an overlay but cannot remember what colour it was, he did not obtain one and
also said, “I would never sit anywhere and get it out, I just wouldn’t use it”. He does not
use mind maps or spider diagrams saying, “They just look like a load of scribble to me”.

Lee is now in the second year of his course.
7.12.2 Report from the Mathematics Learning Support Centre

Lee was assessed for dyslexia during this, his first year, of study. He finds written work difficult; in particular he has slow writing speed and poor spelling. His simultaneous processing is also weak. His working memory causes problems and he rarely remembers spoken instructions. He likes structure and has found the adjustment to independent learning difficult. He has also had problems with fatigue levels and stress.

7.12.3 Report from the Educational Psychologist

The EP's report showed that Lee has an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) of 136. It describes Lee as having relative strengths in verbal reasoning skills and some non-verbal reasoning skills. His relative weaknesses are in visual and auditory short-term memory, auditory working memory, literacy skills and visuo-motor skills. The EP report did not group Lee's results into cluster groups.

The EP's findings are in accord with the interview with Lee and the report obtained from a member of the MLSC. Lee referred to his weakness with literacy skills whereby he needed to re-read material in order to make sense of what he was reading. A member of the MLSC specifically referred to his weakness in auditory short-term memory by saying that he seldom remembered verbal instructions.

The report recommended that Lee be given individual specialist tutorial support for one hour per week, 25% additional time for timed assessments and examinations, computing equipment with appropriate software and a recording device.

7.13 Triangulation of Data

There are points from all of the interviews that are corroborated by the reports from a member of the ELSU, members of the MLSC or the EP reports, which again suggests that the students have honestly reported their individual experiences and are aware of their own difficulties. For example, Edward is self motivated, he visits lecturers if he...
has any problems that have not been addressed in the tutorials and attends the Wednesday afternoon support sessions in the ELSU and this is also verified by a member of that department. Stuart described himself as having difficulties with reading the time and actually remembering what the time is, a member of the MLSC described him as being unable to cope with timetables, schedules and time itself. Alan pointed out that he has co-ordination problems and this is also mentioned in the report from a member of the ELSU. Lee mentioned his difficulties with spelling and the need for independent reading and study at university. A member of the MLSC referred to him as encountering difficulties with written work and in adjusting to independent learning and the EPs report described him as having weakness in literacy skills.

There were not any contradictions evident in the information received from the students, the ELSU, members of the MLSC and the EP reports. However, there were some points raised by members of staff that were not evident from the interviews with the students. For example, a member of the MLSC and a member of the ELSU referred to Stuart as not listening or taking on board advice that was offered. Members of the MLSC referred to Chris as lacking in confidence and James as having a tendency to rush through work.

7.14 The Non-Dyslexic Students

The non-dyslexic students were interviewed during the academic year 2005/2006. The following sections include information that was recorded during one interview; each participant verified that what has been written is correct.

7.14.1 Interview 1: Dan

Dan is a second year Civil Engineering student reading for a MEng degree. He entered university with three GCE A Levels: Mathematics, Physics and Design & Technology, all at grade B. He hasn’t encountered any difficulties that have impeded his progress whilst at university and has a complete set of notes, which he has taken himself. Dan has not experienced any particular difficulty with the mathematics he has encountered and expanded on this by adding, “It’s all a bit baffling at first but then it sort of clicks
and it's OK”. He doesn’t obtain incorrect answers to areas of mathematics that he understands, other than by making occasional careless mistakes. He finds the speed of delivery in mathematics lectures to be “just right”. The tutorials and the MLSC were able to address any queries he has had. The delivery of mathematics is in the format he likes, namely, fully worked examples, which may then be copied from the board followed by an explanation. He hasn’t encountered any forms of testing that proved particularly difficult but pointed out, “The on-line testing is unforgiving, you don’t get any marks for the working”. When asked if he used mind maps for mathematics Dan laughed and said “I’ve got no idea how to do one for maths”.

Dan is now in the third year of his course.

7.14.2 Interview 2: Trev

Trev is a first year Aeronautical student reading for a BEng degree. He entered university with three GCE A Levels: Mathematics, Physics and Electronics, all at grade B. He hasn’t encountered any difficulties that have impeded his progress whilst at university and has a complete set of notes, which he has taken himself. Trev has not experienced any particular difficulty with the mathematics he has encountered and expanded on this by adding, “It’s just that it’s all covered more quickly than at school”. He doesn’t obtain incorrect answers to areas of mathematics that he understands other than by making occasional careless mistakes when working quickly. When asked about the speed of delivery in mathematics lectures he replied, “It’s very fast but I can keep up”. The tutorials were able to address any queries he has had and he has not needed to visit the MLSC. He describes himself as a visual learner and his preferred delivery of mathematics is to be given the theory in bullet points before seeing a worked example. He finds the delivery of mathematics to be acceptable but would like to be given pre-printed notes that he could then annotate. He hasn’t encountered any forms of testing that proved particularly difficult but pointed out, “It’s rather annoying that you can’t get any method marks for the computer tests”. Trev does not use mind maps for mathematics.

Trev is now in the second year of his course.
Dev is a first year Civil Engineering student reading for a MEng degree. He entered university with three GCE A Levels: Mathematics at grade A, History at grade B and Physics at grade D. The difficulties encountered by Dev that have impeded his progress whilst at university have all been related to him not having enough time to complete his tutorial sheets and assignments. He explained that this lack of time was due to his active social life, which incorporates: going to the pub, student union activities and Officer Training Corps. He added that the time problem was compounded by people knocking on his door, e-mailing him, ‘texting’ him and he himself having to address issues such as tidying his room, not remembering to return library books and then having to deal with the ensuing reminders from the library, and more generally having to look after himself and be responsible for his own life. Dev has a complete set of notes, which he has taken himself. He has not experienced any particular difficulty with the mathematics he has encountered and expanded on this by saying, “It’s just the amount of material that is covered and new stuff always seems difficult at first”. He doesn’t obtain incorrect answers to areas of mathematics that he understands. He finds the speed of delivery in mathematics lectures to be “pretty quick” but added, “I love the way he [the lecturer] teaches, it’s like a story unfolding, which he [the lecturer] guides you through”. He found the tutorials to be adequate; they addressed any difficulties he encountered and he has not needed to visit the MLSC. The delivery of mathematics is in the format he likes. It is delivered via an OP and clearly labelled. Dev likes to take down his notes exactly as they are written and does not like handouts. However, he added, “I would prefer to be taught in a class of about 30 rather than these large anonymous groups”. He hasn’t encountered any forms of testing that proved particularly difficult but stressed that he hates on-line tests saying, “I think they are pointless. I recognise the need for accuracy but just one typing mistake leads to zero marks because there isn’t any credit awarded for the method used and the working out”. When asked if he used mind maps for mathematics Dev replied, “I sometimes use them to structure an essay but never for maths, I don’t see how I could do one for maths”.

Dev is now in the second year of his course.
7.14.4 Interview 4: Gary

Gary is a second year Civil Engineering student reading for a BEng degree. He entered university with three GCE A Levels: Physics at grade B, Graphics at grade C and Mathematics at grade D. He has not encountered any difficulties that have impeded his progress whilst at university. Gary has up-to-date notes, which he has taken himself. He has not experienced any particular difficulty with the mathematics he has encountered and doesn’t obtain incorrect answers to areas of mathematics that he understands. He finds the speed of delivery in mathematics lectures to be “OK”. He found the tutorials helpful saying, “I was OK with the tutorial sheets when everything was explained in a bit more detail than in the lectures, the only thing was if lots of people came to them [the tutorials], then there wasn’t enough time to get help with everything”. Gary has visited the MLSC quite frequently and finds it helpful. The delivery of mathematics is in the format he likes, namely, fully worked examples and diagrams. He hasn’t encountered any forms of testing that proved particularly difficult saying, “It’s not the method of testing that makes any difference but sometimes I’m not sure what the question is asking”. When asked if he used mind maps for mathematics Gary replied “No, don’t see how you can do them for maths”.

Gary is now in the final year of his course.

7.14.5 Interview 5: Bella

Bella is a first year Aeronautical Engineering student reading for a MEng degree. She entered university with four grade A GCE A Levels: Mathematics, Further Mathematics, Physics and Russian. She has not encountered any difficulties that have impeded her progress whilst at university. Bella has up-to-date notes, which she has taken herself. She has not experienced any particular difficulty with the mathematics she has encountered and doesn’t obtain incorrect answers to areas of mathematics that she understands. Bella added, “If you understand it [mathematics] you can do it”. She described the speed of lectures as “fast, but OK”. She hasn’t needed to visit the MLSC and when asked if the tutorials addressed any difficulties she was having she responded, “I think they’re a good idea but I haven’t had any problems yet”. The delivery of
mathematics is in the format she likes, namely, fully-worked examples written on a blackboard or OP. She hasn’t encountered any forms of testing that proved particularly difficult saying, “I prefer some more than others but the form of testing doesn’t affect my performance”. When asked if she used mind maps for mathematics Bella replied “I sometimes used spider diagrams for revision but not for maths”.

Bella is now in the second year of her course.

7.14.6 Interview 6: Wayne

Wayne is a second year Civil Engineering student reading for a MEng degree. He entered university with three GCE A Levels: Mathematics at grade A, Design and Technology at grade A and Physics at grade B. He has not encountered any difficulties that have impeded his progress whilst at university. Wayne has up-to-date notes, which he has taken himself. He has not experienced any particular difficulty with the mathematics he has encountered and doesn’t obtain incorrect answers to areas of mathematics that he understands. He described lectures as being, “delivered at a good pace for note taking”. By attending tutorials and occasionally visiting the MLSC he has been able to complete all his tutorial sheets. The delivery of mathematics is in the format he likes, namely, fully worked examples written on a blackboard, whiteboard or OP. He prefers to have diagrams wherever possible and does not like large amounts of text-based material. He hasn’t encountered any forms of testing that proved particularly difficult. When asked if he used mind maps for mathematics Wayne asked, “Are you joking? How do you do one for maths?”

Wayne is now in the third year of his course.

7.14.7 Interview 7: Rachel

Rachel is a second year Civil Engineering student reading for a MEng degree. She entered university with three GCE A Levels: Design & Technology at grade A, Physics at grade B and Mathematics at grade C. She has not encountered any difficulties that have impeded her progress whilst at university. Rachel has up-to-date notes, the
majority of which she has taken herself, occasionally she missed a lecture and then copied them from a friend. She has experienced difficulty with some areas of mathematics saying, “I missed quite a lot of basic schooling from when I was eight and have problems with fractions and percentages. I’m a logical person and stats doesn’t seem logical to me, it was a problem at A Level as well”. If she understands the mathematics she usually obtains the correct answer. Rachel described the pace of lectures as, “Reasonably fast, not too fast though”. By attending tutorials and visiting the MLSC she has been able to address any difficulties she has encountered. She also uses the MLSC to work in. She likes a diagrammatic delivery of material whenever possible and finds the way the material is delivered in mathematics lectures to be generally in the format she likes. She hasn’t encountered any forms of testing that proved particularly difficult. Rachel has used mind maps for design work but never for mathematics.

Rachel passed the second year of her course and is now registered as being on leave.

7.14.8 Interview 8: Nico

Nico is in his first year reading for a BEng in Aeronautical Engineering. He entered university with four GCE A Levels: Mathematics, PE and General Studies at grade A and Physics at grade B. He encountered some difficulties that impeded his progress whilst at university. He explained, “I’ve not really settled in yet and I’m spending too much time travelling back home to play sport”. He has notes that he has taken himself or copied from friends as he has missed quite a lot of lectures. He has only experienced difficulty with matrices, which he described as “confusing”. When asked if there were any areas of mathematics that he understood but frequently obtained incorrect answers to he replied, “No, you see with mathematics if you understand it you generally get it right”. He described the pace of lectures as being “very quick”, and added, “There’s no interaction in lectures, I preferred the small classes we had at school where everyone participated”. He has found that the tutorials have addressed any difficulties he has encountered and has not visited the MLSC. He prefers a diagrammatic delivery where possible with material written on a blackboard. He finds the way the material is delivered in mathematics lectures to be in the format he likes but containing too much
detail. Nico has not encountered any forms of testing that proved particularly difficult but added, “The computer tests are a bit cruel, one mistake and that’s it, no marks”. When asked if he used mind maps for mathematics he said, “I was taught at school, I’m quite artistic and like drawing them but I’ve never done one for maths”.

Nico failed several modules and is now re-sitting the first year of his course.

7.14.9 Interview 9: Andrew

Andrew is a second year Civil Engineering student reading for a BEng degree. He entered university with three GCE A Levels: English Literature at grade A, Mathematics at grade C and Physics at grade D. He has encountered some difficulties that have impeded his progress whilst at university. He explained, “I’ve not got a very good memory, I’ll learn it all for exams but forget it all afterwards, I’m always having to look things up because I’ve forgotten them”. Andrew has up-to-date notes, which he has taken himself. He only experienced difficulty with statistics saying, “The whole subject is confusing, it’s not as set in stone as pure maths”. When asked if there were any areas of mathematics that he understood but frequently obtained incorrect answers to he replied, “No, the problem is with the stuff you don’t understand because once you understand it then you can do it”. He described the pace of lectures as “quite quick” and added, “Sometimes I’m too busy trying to copy it down neatly to listen to what the lecturer is saying”. He has found the tutorials helpful and has also visited the MLSC. He prefers a diagrammatic delivery whenever possible, with material being written on the blackboard. The way the material is delivered in mathematics lectures is generally in the format he likes. Andrew hasn’t encountered any forms of testing that proved particularly difficult but added, “CAA doesn’t seem very fair you don’t get any method marks”. When asked if he used mind maps for mathematics he said, “No, not for anything”.

Andrew is currently undertaking a year in industry.
Jon is a second year Civil Engineering student reading for a BEng degree. He entered university with three GCE A Levels: Mathematics and French both at grade B and Physics at grade D. He has not encountered any difficulties that have impeded his progress whilst at university and has up-to-date notes, which he has taken himself. He has only experienced difficulty with statistics saying, “I can’t see a logical pattern and always seem to do something wrong like use the wrong distribution or the wrong table”. When asked if there were any areas of mathematics that he understood but frequently obtained incorrect answers to he replied, “Yes, matrices but that’s because I’m sloppy with arithmetic”. He described the pace of lectures as “perfect”. He has found that by attending tutorials and visiting the MLSC he is able to address any difficulties that he encounters. He prefers a diagrammatic delivery where possible with material written on the blackboard followed by an oral explanation and finds the way the material is delivered in mathematics lectures to be in the format he likes. Jon hasn’t encountered any form of testing that proved particularly difficult but added, “CAA doesn’t give you any marks for the working so no-one knows if you were just guessing or made a small mistake”. When asked if he used mind maps for mathematics he said, “No, they taught us in school but I don’t like them and never use them for anything”.

Jon is currently undertaking a year in industry.

Brad is a mature first year Civil Engineering student reading for a BEng degree. He completed a Foundation Course as he left school after taking his GCSE examinations. He has not encountered any difficulties that have impeded his progress whilst at university but finds the workload to be heavy. He has up-to-date notes, which he has taken himself. He has only experienced difficulty with calculus, which he attributes to his non A Level background. If he understands the mathematics he is able to obtain correct answers. He described the pace of lectures as “quite quick” and added, “I can take the notes or listen but not both”. He has found the tutorials to be excellent saying, “Not many people went to them and I was able to get a lot of help. Anything that I
didn't manage to get sorted I took to the MLSC". Brad prefers to be given a
diagrammatic representation where possible with step-by-step worked examples
delivered via the blackboard or OHP. He finds the way the material is delivered in
mathematics lectures to be in the format he likes but he would also like to be given
handouts. Brad found the multi-choice diagnostic test problematic saying, "All the
answers were so similar I got confused". When asked if he used mind maps for
mathematics he said, "Is that a serious question, surely they're no use for maths".

Brad is now in the second year of his course.

7.14.12 Interview 12: Barry

Barry is a first year Civil Engineering student reading for a BEng degree. He entered
university with four GCE A Levels: General Studies at grade C, Mathematics at grade D
and Biology and Physics both at grade E and has completed a Foundation Course. He
has encountered some difficulties that have impeded his progress whilst at university
but these have all been due to his social life and sporting interests. He has up-to-date
notes, which he has taken himself. The only area that he has experienced problems with
is calculus, which he attributes to his poor A Level result. If he understands the
mathematics he is able to obtain correct answers although he occasionally makes
careless mistakes with numbers, especially in statistics. He used the MLSC during his
foundation year but this year the tutorials have been able to address any difficulties he
encountered. Barry likes diagrams and bullet points to be used with delivery via a
blackboard or OHP. He likes to write the notes himself and does not like printed
handouts. He finds the way the material is delivered in mathematics lectures to be in the
format he likes. He hates all examinations but found CAA to be the easiest as he could
use his notes, and multiple choice to be the hardest. This, he explained, is because, "All
the options are similar and I end up convinced that several of them could be right".
When asked if he used mind maps for mathematics he said, "I've used them for group
project work to record brainstorming sessions but never for maths or any other subject".

Barry is now in the second year of his course.
7.15 Findings from the Case Studies and Interviews

The Research Design for the explanatory case studies (see Appendix C.3) contains ten hypotheses. Using cross-case synthesis the findings from each of the dyslexic case studies and the non-dyslexic students’ interviews are linked to these hypotheses.

Hypothesis 1: Dyslexic students experience difficulty with note taking.

Table 21 shows the dyslexic and non-dyslexic students who have difficulty in this area.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
</tr>
<tr>
<td>Phyllis</td>
<td>Trev</td>
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<tr>
<td>Stuart</td>
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<td>Alan</td>
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<td>Joseph</td>
<td>Brad</td>
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<tr>
<td>Lee</td>
<td>Barry</td>
</tr>
</tbody>
</table>

Table 21: Difficulties with Note Taking

Of the dyslexic students, ten experienced difficulties with note taking. Of these students, five stated that they were unable to listen to what the lecturer was saying as they were still copying down material, whereas only two of the non-dyslexic students experienced difficulty with this.

Daniel, who only experienced problems during his foundation year, has not been listed as having difficulties in this area. Two of the dyslexic students (Anthony and Joseph) now have note takers but emphasised that prior to this they experienced difficulties and Anthony added that he still experiences problems with his notes due to unclear labelling of them by the note taker.
Three of the non-dyslexic students specifically referred to mathematical material as being delivered at an ideal pace for note taking.

**Hypothesis 2:** Dyslexic students experience difficulties with multi-stage mathematical operations.

Table 22 shows the dyslexic students who have difficulty with multi-stage mathematical operations.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>√ Dan</td>
</tr>
<tr>
<td>Phyllis</td>
<td>Trev</td>
</tr>
<tr>
<td>Stuart</td>
<td>√ Dev</td>
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<td>James</td>
<td>√ Nico</td>
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<td>Jack</td>
<td>√ Andrew</td>
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<td>Bob</td>
<td>√ Jon</td>
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<td>Joseph</td>
<td>Brad</td>
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<tr>
<td>Lee</td>
<td>Barry</td>
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</tbody>
</table>

Table 22: Difficulties with Multi-Stage Mathematical Operations

None of the non-dyslexic students referred to any difficulties being experienced whereas five of the dyslexic students referred to this as being an area of particular difficulty.

**Hypothesis 3:** Some dyslexic students experience visual problems, which results in difficulties being encountered when working with rows/columns of figures and equations.

As shown in Table 23, eight of the dyslexic students cited difficulties being experienced in this area whereas none of the non-dyslexic students referred to themselves as experiencing any difficulty whatsoever.
### Table 23: Visual Difficulties

**Hypothesis 4: Dyslexic students encounter difficulties with descriptive text.**

Table 24 shows the dyslexic and non-dyslexic students who have difficulties in this area.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
</tr>
<tr>
<td>Phyllis</td>
<td>Trev</td>
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<td>Stuart</td>
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<td>Joseph</td>
<td>Brad</td>
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<tr>
<td>Lee</td>
<td>Barry</td>
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</tbody>
</table>

### Table 24: Difficulties with Descriptive Text
Eight of the dyslexic students encountered difficulties with descriptive or dense blocks of text. In particular, Phyllis mentioned that it was easier to absorb material of an auditory nature rather than through a visual representation. Stuart did not specifically refer to difficulty in this area, however a member of the MLSC described his poor reading skills and the necessity to highlight important words for him.

None of the non-dyslexic students mentioned difficulties in this area although Wayne expressed the opinion that he does not like large amounts of text-based material.

**Hypothesis 5:** Dyslexic students experience difficulties with the recall of notation and formulae.

Table 25 shows the dyslexic and non-dyslexic students who have difficulties in this area

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
</tr>
<tr>
<td>Phyllis √</td>
<td>Trev</td>
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<td>Stuart</td>
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</table>

Table 25: Recall of Notation and Formula

Four of the dyslexic students and none of the non-dyslexic students experience difficulty in this area. It is surprising that so few of the dyslexic students have problems with the recall of notation and formulae as many texts on mathematics for dyslexic schoolchildren frequently refer to this as being an area fraught with difficulty. See for example, T.R. Miles (1992:3) and Henderson and Miles (2001:1-6). One explanation for this might be that these texts are written for dyslexic children of varying mathematical
ability whereas the students participating in these studies have succeeded at school mathematics.

Hypothesis 6: Tutorial support is inadequate for the problems experienced by dyslexic students.

As shown in Table 26, eight of the dyslexic students found this to be the case whereas none of the non-dyslexic students were of this opinion.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
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<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
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<td>Phyllis</td>
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</table>

Table 26: Tutorial Support is Inadequate

However, two students, Edward (dyslexic) and Gary (non-dyslexic) mentioned that if a large number of students attended the tutorials then there was insufficient time available to address any problems they might have.

There were conflicting comments received concerning postgraduate students taking tutorials. Jack, a dyslexic student, found the tutorials to be good and the postgraduate students to be more in touch with the mathematical ability of the undergraduates than lecturers, whereas Alan and Phyllis, both dyslexic students, found that postgraduates often used different methods to those of the lecturer. Lee, another dyslexic student also mentioned that one postgraduate student had very poor spoken English.
Hypothesis 7: Drop-in support at the MLSC is inadequate for the needs of dyslexic students.

Table 27 shows that six of the dyslexic students found the MLSC to be inadequate for their needs, whereas this was not the case with the non-dyslexic students who had found it to be helpful or had not needed to visit it. Edward and Chris, both dyslexic students, mentioned that the MLSC was only helpful at times when it was not busy.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
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<tr>
<td>Phyllis</td>
<td>Trev</td>
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<tr>
<td>Stuart</td>
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<td>Joseph</td>
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<td>Lee</td>
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</table>

Table 27: Drop-In Support at the MLSC is Inadequate

The main reason cited by the dyslexic students as to why the MLSC was not meeting their needs was insufficient time with the lecturer on duty. Other reasons were that the lecturers on duty were so clever that they were unable to relate to the students, the room was too noisy, the help was variable depending on the lecturer on duty and that it was off-putting to see so many different lecturers. This is in accord with findings from the exploratory studies and the one-to-one support. Robert (Chapter V, section 5.2.1) found the help not to be at the level he required; it was the support from his one-to-one tutor, who explained the mathematics in greater detail to him, which was most helpful. Patrick (Chapter VI, section 6.1) generally needed more help than was available at a drop-in session; he needed to understand where a particular topic fitted into the mathematics he had already encountered and the areas in which it could be used.
Chapter X will look explicitly at the MLSC. However, questions have been asked here in the explanatory studies and during the one-to-one support sessions (Chapter VI) as it was envisaged that the lengthy questionnaire used for the MLSC study might deter many dyslexic students from completing it. The findings from this hypothesis will be referred to again in Chapter X.

**Hypothesis 8:** Some methods of mathematical delivery and/or assessment are unfair to dyslexic students.

Table 28 shows that six of the dyslexic students found the delivery of material to be in a format that was difficult for them and 11 of these students had problems with current assessment methods. Of the non-dyslexic students, all found the delivery of mathematical material to be in an acceptable format and only two students had encountered difficulties with current assessment methods.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delivery</td>
</tr>
<tr>
<td>Edward</td>
<td>✓</td>
</tr>
<tr>
<td>Phyllis</td>
<td>✓</td>
</tr>
<tr>
<td>Stuart</td>
<td>✓</td>
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<tr>
<td>Alan</td>
<td>✓</td>
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<td>Daniel</td>
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<td>Chris</td>
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<td>Anthony</td>
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<td>Jack</td>
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<td>Bob</td>
<td>✓</td>
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<tr>
<td>Joseph</td>
<td>✓</td>
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<tr>
<td>Lee</td>
<td>✓</td>
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</tbody>
</table>

Table 28: Some Methods of Mathematical Delivery and Assessment are Unfair

The dyslexic students predominantly cited difficulties with assessment. There are, however, notable differences between them, for example, James and Daniel prefer CAA, whereas six dyslexic students specifically mention CAA as being problematic. Multi-choice examinations also gave rise to difficulties amongst seven of the dyslexic
students but only two of the non-dyslexic students. This is, in the main, due to confusion between similar answers and in the case of dyslexic students the answer boxes being located too close together, which gives rise to problems amongst those who experience visual disturbance. In written examinations two of the dyslexic students referred to the number of transcription errors they made, as, due to their large handwriting, they frequently had to turn to a new page in the answer booklet.

Amongst the ten non-dyslexic students who did not experience any difficulty with current methods of assessment six of them referred to CAA as being cruel, unforgiving or unfair.

Hypothesis 9: Dyslexic students learn and revise differently to non-dyslexic students.

Only one question relating to the use of mind maps for mathematics was asked, the answers to which proved to be particularly illuminating and are shown in Table 29.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use Mind Maps for Mathematics</td>
<td>Use Mind Maps for Mathematics</td>
</tr>
<tr>
<td>Edward</td>
<td>√</td>
</tr>
<tr>
<td>Phyllis</td>
<td>√</td>
</tr>
<tr>
<td>Stuart</td>
<td>√</td>
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<td>Alan</td>
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<td>Daniel</td>
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<td>Anthony</td>
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<td>Joseph</td>
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<td>Lee</td>
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</tbody>
</table>

Table 29: Use of Mind Maps for Mathematics

Eight of the dyslexic students used mind maps to help them understand and recall mathematical material. Interestingly seven of these students preferred to draw the mind maps themselves even though many of them had been supplied with software designed
for this purpose. None of the non-dyslexic students used mind maps for mathematics either as an aid to revision or understanding and most of these students were bemused as to how mind maps could be used for mathematics. Although the students were not specifically asked whether they needed a ‘global picture’ of the material they were encountering (it was decided that this would have been a leading question) five of the dyslexic students referred to this whereas none of the non-dyslexic students referred to this. The need to see the whole picture was also evident in the students who received one-to-one support (Chapter VI).

**Hypothesis 10:** Dyslexic students may understand some areas of mathematics but frequently obtain incorrect answers.

Table 30 shows that all of the dyslexic students matched this hypothesis as opposed to only one of the non-dyslexic students, which is in accord with the findings from the one-to-one support case studies.

<table>
<thead>
<tr>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Dan</td>
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<td>Phyllis</td>
<td>Trev</td>
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<td>Joseph</td>
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</table>

Table 30: Understand Material but Obtain Incorrect Answers

Jon (a non-dyslexic student) attributed this to his being sloppy with arithmetic. Three of the non-dyslexic students said that they occasionally obtained incorrect answers due to working at speed or through making the odd careless mistake and a further three
expressed the opinion that if material had been understood then correct answers would be obtained.

The triangulation of data has, in many cases, verified the findings from the interviews with the dyslexic students. Moreover, it is believed that the students were interested in the study and realistic with the comments they made, for example James referred to the speed of delivery in lectures but appreciated that the lecturer had to cover a great deal of material.

A summary of the findings for each of the hypotheses is shown in Table 31.

<table>
<thead>
<tr>
<th>Hypothesis Number</th>
<th>Dyslexic Students</th>
<th>Non-Dyslexic Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Note Taking)</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>2 (Multi-stage Operations)</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>3 (Visual Disturbance)</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>4 (Descriptive Text)</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>5 (Recall of Notation and Formulae)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>6 (Tutorial Support)</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>7 (MLSC)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>8 (Delivery/ Assessment)</td>
<td>6/11</td>
<td>0/2</td>
</tr>
<tr>
<td>9 (Mind Maps)</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>10 (Understand but Obtain Incorrect Answers)</td>
<td>12</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 31: Findings for Each of the Hypotheses

One question that was posed to both the dyslexic and non-dyslexic students was 'Whilst at university have you experienced any general difficulties that impeded your progress?' Some difficulties, apart from those specifically addressed by the hypotheses, emerged. Amongst the dyslexic students these included misreading information on timetables resulting in lectures being missed, co-ordination problems, organisational skills and short attention span. Whereas the reasons cited by the non-dyslexic students were related to social life and outside interests.

Questions were specifically asked about usage of equipment, software and one-to-one support provided by the DSA. Some of the dyslexic students in this study have referred
to recording devices and read and writes packages as not being suitable for their area of study and many of the students who have been provided with software for drawing mind maps do not use it as they prefer to draw their own. All the students who were receiving one-to-one support found it to be helpful. This is an area of some concern as dyslexic students account for a high proportion of all disabled students (Chapter I). The maximum amount that was available (not all students will receive the maximum) through the DSA for the academic year 2006/2007 was £4,795 for specialist equipment (this covers the duration of a course), a non-medical helper’s allowance of up to £12,135 per year, and a General Disabled Students’ Allowance of up to £1,605 per year (DfES, 2006:13).

7.16 Conclusion

It is apparent that all of the dyslexic students who participated in this research are disadvantaged in some areas of their study of mathematics both as a direct result of their dyslexia (note taking, multi-stage operations, descriptive text, visual disturbance and recall of material) and as a result of current practices in the delivery (lack of handouts and tutorial support) and assessment procedures (lengthy examinations, multiple-choice examinations and CAA) in use at Loughborough University. What is also apparent is that the dyslexic students have differing requirements, for example some students would like handouts prior to the lecture, others after the lecture. Regarding assessment procedures, it is evident that particular care needs to be given to the design of multiple-choice assessments to avoid confusion with the answer boxes for those students who have visual disturbance. Additionally, the provision of loose sheets of paper, rather than an answer booklet, might help to reduce transcription errors that may be made due to frequent turning over of the pages. Moreover, the timetabled tutorials and the drop-in support at the MLSC provide inadequate support for the majority of dyslexic students.

The findings from this study provide sufficient evidence to justify the acceptance of the hypotheses that were made. It is recommended that academic staff undergo training to enable them to recognise the difficulties that may be encountered by dyslexic students and to raise awareness of the needs of these students. It is also recommended that
additional staff should be made available in the MLSC to ensure that adequate time can be spent with students using this facility.

Furthermore, the findings from these explanatory studies corroborate the findings from the one-to-one case studies, which increases the internal validity of this research.
This chapter reports the findings from an exploratory study, undertaken in May 2005, which was set up to investigate whether dyslexic students are disadvantaged by CAA of mathematics, the effects that different media combinations might have on both dyslexic and non-dyslexic students, and whether this form of testing gives a realistic indication of mathematical ability. Dr. Nigel Beacham obtained funding from the HEA to investigate the effects that different media combinations might have on the results of students undertaking CAA.

The study was undertaken with first year undergraduate students reading for a degree in Engineering at Loughborough University. The topic chosen for the study was that of basic integration. The CAA consisted of three versions; Version 1 contained a text only representation, Version 2 contained text and a graphical representation and Version 3 contained text and an audio representation. In setting up this study, the author of this thesis was responsible for the mathematical areas and the paper based questionnaires and Beacham for setting up the CAA.

8.1 Introduction and Background to the Study

The author of this thesis became interested in CAA as a result of low marks obtained in this form of testing by Patrick (Chapter VI, section 6.1.1) and Alan (Chapter VII, section 7.4.1) and, which led them to suspect that they might be dyslexic. A definition of CAA given by 'Questionmark' (www.questionmark.com/uk/glossary.htm) is "A common term used to describe the use of a computer to support assessments". This form of assessment is being increasingly used in HE alongside the more traditional forms of evaluation such as examinations and coursework. Initially, this form of testing was predominant in scientific disciplines; however, Chalmers and McAusland (2002) have found that it is now being progressively used in the fields of social sciences and humanities. Once a bank of questions has been developed and the system has been
implemented, CAA enables a large number of students to be tested on a regular basis. Additionally, it provides immediate feedback to both academic staff and students, and, as manual marking of scripts is not required, it also reduces the workload of staff.

There is growing awareness and concern regarding the effect that media representation might have on the process of learning. Previous work undertaken by Beacham, Szumko and Alty (2003), investigated the use of multimedia in CAA in the field of statistics. Students were divided into three groups and presented with a text only, a text and diagram or a sound and diagram version. It was found that the dyslexic students scored highest on the text only version and lowest on the sound and diagram version. Conversely, non-dyslexic students scored highest on the sound and diagram version. One possible explanation of this result was that the dyslexic population, many of whom are visual and global thinkers, were disadvantaged by the assessment being predominantly word based and encountered a memory overload when the material was presented in more than one form of media. Direct comparison with this earlier work is not viable as it involved a different topic and different media representations to those used in this study.

Individuals have many different learning styles (Chapter II, section 2.4.1.1) and those with SpLDs may have additional requirements. Wiles (2002) offers some guidance, which includes avoiding overly complex answers to multiple-choice questions as dyslexic students may be unable to identify subtle distinctions or need longer to determine them. She recommends that the students themselves should be allowed to decide how long they want to spend on each individual question and feels that extra time may make examinations more arduous for students with disabilities. Greenhow (2000:23) recommends that attention be paid to the size of font and background colouring to accommodate those who may be colour blind or visually impaired.

In December 2004, the MEC at Loughborough University set up the Assessmedia Project to investigate the effects that different media combinations might have on the results of students undertaking CAA. Motivation for the study arose from concerns appertaining to whether or not lecturers need to have greater understanding of the suitability of different media combinations when used in CAA. This exploratory study, funded by the HEA, formed part of the aforementioned project.
With the growing number of dyslexic students entering HE (Chapter III) and to comply with SENDA (Chapter I), it is imperative to determine whether CAA discriminates against disabled students. There are guidelines for the use of technology-based assessment, for example: JISC TechDis (2003) and the SPACE Project (Chapter II, section 2.4.2), which is currently investigating inclusive approaches to assessment. Nevertheless, regarding the area of mathematics and CAA, there does not appear to be any published work or evidence of research on the use of multimedia forms of this testing for either dyslexic or non-dyslexic students.

The use of CAA for mathematics is well established. However, one area of concern is that marks are, in the main, only awarded for a correct answer. There is research in this area being currently undertaken, for example, Sangwin, Ward, Croft and Xie. Their work, as yet unpublished, has determined that it is feasible for many of the questions in GCE A level material to be awarded partial credit.

In mathematics, the awarding of marks for correct answers has particular implications especially for questions that require lengthy calculations to be undertaken. For example, a student may have correctly identified the method to be used, undertaken lengthy computation and then made an error at a late stage of the calculation and thus receive a mark of zero for that particular question. As dyslexic students are known to make frequent transcription errors, it may transpire that this form of testing places them at a disadvantage, when compared to non-dyslexic students.

This study builds upon earlier research conducted by Beacham, Elliott and Alty et. al., (2002:111-116) into media combination and learning styles, and experiments undertaken by Beacham and Alty (2004) involving the use of interaction. Traditionally, material used for CAA at Loughborough University has been presented as text only, with diagrams only being included when they are essential, for example, in questions relating to vectors and Argand diagrams. In the HELM bank of questions (Green, Harrison & Palipana et. al., 2004), which contains over 4500 test items, only approximately 6% of these contain diagrams.

The material in the CAA for this study was presented as three different versions; Version 1 contained text only, Version 2 contained text and diagrams (a graphical
representation) and Version 3 contained text and audio. The topic of basic integration as encountered by first year electronic and electrical engineering students was selected for this study. This topic forms part of a double weighted mathematics module, which covers and builds upon material that has been encountered in GCE A Level mathematics and also introduces new topics.

The purpose of this module is to ensure that these first year students with differing levels of mathematical knowledge gained from diverse mathematical backgrounds will all be familiar with the essential mathematical techniques that will underpin material in future mathematics and engineering modules. In addition to a summative examination, which is taken at the end of the academic year, individual topics are tested throughout both semesters using CAA. Practice CAA tests are available for students to attempt, if they wish to do so, one week prior to the marked CAA. Integration was chosen as this topic lends itself easily to a graphical representation and, as the questions did not involve a large amount of text, it was not a protracted task to add audio to them.

8.2 Methodology

The HELM bank of questions, which is used for CAA at Loughborough University, was accessed to obtain questions for this study. This ensured that this study would be comparable, in terms of question length and complexity, to the questions that would be encountered by the students in their marked CAA on integration. The study was scheduled to take place during one of the timetabled tutorial sessions, for students undertaking this module, in the week preceding their CAA test on integration and just prior to the practice CAA test being made available.

Considerable time was taken in the selection of the questions to be used to ensure that a variety of functions and methods were tested. Three questions that it was believed might prove problematic to dyslexic students were selected and two questions were chosen as it was believed that a graphical representation might be helpful to the participants of Version 2. The five integrals that were selected contained an assortment of trigonometric, exponential, polynomial and hyperbolic functions. The chosen questions
were presented as they appeared in the HELM question bank. These questions and the reasons for their selection are given in section 8.3.

The three versions of the CAA were prepared by using the CAA development tool Perception. This tool was deemed to be the most appropriate as it is has a central role in the university’s e-learning strategy, is available to all staff and had been used to produce the HELM bank of CAA questions. To produce Version 1 of the test, the questions that had been chosen were copied directly from the HELM bank. For Version 2, a graph of each function between the upper and lower limits of its associated integral, with the area under consideration shown in colour, was created in Maple. These graphs were saved as images and then placed in the relevant question item. Version 3 was produced by first accessing the questions and then writing all mathematical notation and Greek letters as text, for example, $\theta$ was replaced by theta. Additional punctuation was also added to ensure that pauses in the speech would occur where required. These adapted questions were then copied into a screen reader and the speech output saved as an audio file. Each audio file was then placed in the relevant question item.

There were 127 students registered on this module, which included 12 students who were known to have the SpLD dyslexia. The lecturer responsible for delivery of this module agreed to ask the students to participate in the study. All students, who were present at the first lecture on integration, were invited to participate and informed that they would receive a small honorarium for their participation. It was also pointed out to them that this study would provide additional practice for their CAA on integration, as it would be undertaken prior to the practice CAA tests becoming available. Furthermore, all students registered on the module were subsequently contacted by email, which ensured that those who had been absent from the lecture were made aware of the study.

A total of 36 students agreed to participate in the study and their consent was obtained via e-mail. A member of academic staff with access to student records divided these students into three groups, with each group containing some dyslexic students and students with a range of prior mathematical achievement. These three groups were then assigned to a particular test. Group 1 was assigned to Version 1 (text only), which formed the control group; Group 2 was assigned to Version 2 (text and diagram) and Group 3 to Version 3 (text and audio).
Questionnaires requesting participating students' opinions of CAA, the number of times (on average) they referred to the displayed questions in previous tests, the number of times they referred to the questions or listened to the questions in this study and their opinion of the particular test they had undertaken were designed. Personal details relating to age, highest pre-university mathematical attainment and particulars of any SpLD were also requested. The questionnaire and personal details documents may be viewed in Appendix D. Paper was provided for the students' rough working and collected at the end of the test to enable manual marking and further analysis to be undertaken.

8.3 The Questions Selected and the Reasons for their Selection

**Question 1:** Find the average value of the function $f(x) = x - \cos(\pi)$ across the interval $0 \leq x \leq \frac{\pi}{2}$. [1 mark]

This question was selected not only to test whether students could remember how to find the average value of a function but also because it was considered that students might read the $\cos(y)$ term, which is a constant, as the function $\cos(x)$. It was considered of interest as to whether the Version 2 test with the graphical representation, clearly showing that $f(x)$ is linear, would prevent students from making this mistake.

**Question 2:** Find the volume of the solid formed when $y = \cos(2x)$, between $x = 0$ and $x = \frac{\pi}{4}$, is rotated about the x-axis. [1 mark]

As the volume generated is 3-dimensional this question requires a visual conceptualisation, which is an area in which many dyslexic students are known to be strong (Singleton, 1999:29-30). The question was also selected to test whether the students could remember how to find the volume of the solid formed when a function is rotated. Additionally, students need to be able to select and use appropriate trigonometric identities. For those students who used a calculator, it would also test whether they appreciated the difference between selecting radians or degrees.
Question 3: Find the total area enclosed between the x-axis and the curve 
\( y = e^{-x} - 1 \) between \( x = -1 \) and \( x = 1 \). [1 mark]

This question was selected as it was considered that students might obtain \( e^x \) as the integral of \( e^{-x} \) rather than the correct answer of \(-e^{-x}\). It was also considered that dyslexic students, in particular, might misread the term \( e^x \) as \( e^x \). From mistakes witnessed in tutorial sessions it was expected that students might fail to split the integral as shown below:

\[
\int_{-1}^{0} (e^{-x} - 1)\,dx + \left| \int_{0}^{1} (e^{-x} - 1)\,dx \right|.
\]

It was deemed of interest as to whether the Version 2 test with the graphical representation would prevent students from making this mistake. This question would also test whether students appreciated that \( e^0 \neq 0 \).

Question 4: Determine the value of the following integral \( \int_{2}^{2.001} (4x)\,dx \). [1 mark]

This question was selected as it was considered that dyslexic students, in particular, might misread the upper limit of the integral as either 2.01 or 2.0001.

Question 5: Determine the value of the following integral \( \int_{1}^{2} (x\cosh(x))\,dx \). [2 marks]

This question was selected to test whether students could recognise the need for integration by parts and correctly apply this process, and also test their familiarity of hyperbolic functions. Additionally, it was considered that dyslexic students, in particular, might misread the lower limit of integration as 1.

8.4 Development and Final Content of the Test

On listening to the audio output it became evident that some additional punctuation needed to be added. Question 3 also posed a problem as it appeared that the function to be integrated was \( y = e^{-x-1} \) rather than \( y = e^{-x}-1 \); this question was subsequently changed,
in all three versions, to \( y = -1 + e^x \). The finalised three versions were then published. Publication entailed the uploading of each version to a central web server and assigning to each test the names of those participants allowed to access them. The finalised questions for Version 2 are shown below.

**Q1.** Find the average value of the function \( f(x) = x - \cos(\pi) \) across the interval. 
\( 0 \leq x \leq \pi/2 \).

Enter your answer, correct to 2d.p., in the box provided. [1 mark]

**Q2.** Find the volume of the solid formed when \( y = \cos(2x) \) between \( x = 0 \) and \( x = \pi/4 \) is rotated about the x-axis.

Enter your answer, correct to 2d.p., in the box provided. [1 mark]
Q3. Find the total area enclosed between the x-axis and the curve $y = -1 + e^x$ between $x = -1$ and $x = 1$.

Enter your answer, correct to 2d.p., in the box provided. [2 marks]

Q4. Determine the value of the following integral:

$$\int_{2}^{2.001} (4x) \, dx.$$ 

Enter your answer, correct to 2d.p., in the box provided. [1 mark]

Q5. Determine the value of the following integral:

$$\int_{-1}^{2} (x \cosh(x)) \, dx.$$ 

- 241 -
Once published, all three versions were tested in the computer laboratory in which the tests were scheduled to take place. Whilst there were not any major technical difficulties, problems were experienced with Version 3. To ensure that participants would actually listen to the question, this version had been designed to automatically play the associated audio file when a question was accessed. When accessing this test remotely, all the audio files are downloaded to the client machine ready to play. Unfortunately, on the laboratory computers, once one student had accessed the first question it was played to all participants who accessed this version. As a result of this problem it was decided to remove the auto-play set-up and instruct students to access the audio delivery of each question at least once. The options to pause, to stop, to rewind and to forward the audio file were available.

8.5 Modus Operandi

Participants were allowed to attempt the questions in any order and revisit questions, prior to submission, if they wished to do so. The computer laboratory, where the test was conducted, was booked for one hour, which placed an upper bound on the time available for students to complete the test. Included in this time was the registering of students as they arrived and student completion of the post-test questionnaire and personal details document. However, as the CAA, which forms part of the assessment
procedure for this module, would contain 6 questions with a time allowance of 1 hour or up to 1.25 hours for those students who are entitled to extra time in examinations, it was considered that students would not be under any time pressure when undertaking this test containing five questions.

Unlike the current CAA assessment procedure, students were not allowed access to their lecture notes or textbooks; however, formulae booklets and calculators were permitted. Participants of Version 3 were provided with headphones. All students were provided with paper to be used for the computation of their answers, which was attached to the post-test questionnaire and personal details sheet and collected at the end of the test. Later analysis of the students' paper-based calculations would enable their working to be scrutinised to determine whether the original question had been correctly transcribed, whether the correct method had been utilised but a mistake made somewhere in the calculation and if the answer obtained agreed with that entered into the computer.

Of the 36 students, who had agreed to participate in the study, only 15 arrived at the scheduled time. The students who had failed to attend were subsequently contacted by email and new dates and times were arranged with those that responded. Some additional students, who had not initially agreed to participate, offered to take part. Unfortunately, this affected the balance of dyslexic students and prior mathematical achievement between the groups. In total there were 30 participants, eight of whom were dyslexic. Each group consisted of 10 students. The number of dyslexic students varied between the groups; there were five in Group 1, two in Group 2 and one in Group 3.

8.6 Results from the CAA

This study did not show any significant differences in the marks obtained or the time taken between the different media combinations. Participants took between 8 and 56 minutes to complete the test, with the average time taken being 30.7 minutes. The average time taken by students undertaking each version was:

Version 1  31.26 minutes
Version 2  32.01 minutes
The dyslexic students took an average time of 27.38 minutes and scored an average mark of 17.7%. Non-dyslexic students took an average time of 31.94 minutes and scored an average mark of 28.5%. This suggests that the time available is not having an adverse affect on the performance of dyslexic students. In Version 1, which had an even distribution of dyslexic and non-dyslexic students the non-dyslexic students took an average time of 32.08 minutes and scored an average mark of 25.6%, and the dyslexic students took an average time of 30.44 minutes and scored an average mark of 17%. Due to the small sample sizes and the uneven distribution of dyslexic students between the three versions statistical analysis is not considered to be viable.

The average score per group and the number in each group who correctly answered each question are shown in Table 32.

<table>
<thead>
<tr>
<th>Question</th>
<th>Version 1 (text only)</th>
<th>Version 2 (text and diagram)</th>
<th>Version 3 (text and audio)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average score = 21.3%</td>
<td>Average score = 22.9%</td>
<td>Average score = 32.7%</td>
</tr>
<tr>
<td></td>
<td>Number giving correct answer</td>
<td>Number giving correct answer</td>
<td>Number giving correct answer</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 32: Number of Students in Each Version Who Gave Correct Answers

As can be seen, Version 3 students obtained a significantly higher average mark than the other two groups. The original grouping of students had included an equal distribution of dyslexic students and ability; unfortunately, the students who did not actually take the test sabotaged this. As this test was taken before the practice tests became available, it was considered likely that the students would not have started revising for their CAA on integration. To determine whether the Version 3 participants were more mathematically competent that those undertaking Versions 1 and 2 a
comparison was made with the marks obtained in a diagnostic test undertaken by these students on entry to university, for which they did not have time to prepare. This confirmed that the students undertaking Version 3 had also scored more highly on their initial diagnostic test. The average marks obtained in the diagnostic test were, Version 1 students 66%, Version 2 students 70% and Version 3 students 75%.

The results of this exploratory study do not suggest that dyslexic students are disadvantaged by CAA. It is also indicated that the different media combinations, as presented in this CAA test, did not have a significant effect on the scores obtained or the time taken to complete the test. What did emerge, through detailed analysis of the students’ paper-based working, were the shortcomings in CAA, which fails to pick up where students are going wrong, and penalises students for minor errors in largely correct pieces of work.

8.7 Analysis of the Scripts

A detailed analysis of the students’ paper-based calculations was then undertaken. This was carried out to determine if there were any incidents of students correctly computing the question but making an error when keying in the answer, whether students had made a transcription error when initially writing down the question and whether they had made a small mistake towards the end of the question but employed the correct method. The results of this analysis are shown in Table 33, the letter d after a number indicates dyslexic student(s).

Investigation of the two questions where it was considered that a graphical representation might be helpful to students did not reveal this to be the case. Of the students who attempted questions 1 and 3, the number who failed to recognise that \( \cos(t) \) was a constant (question 1) and the number who failed to split correctly the integral into two parts (question 3) are shown in Table 34.
<table>
<thead>
<tr>
<th>Question No.</th>
<th>Analysis of Paper-based Working</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Correct</td>
<td></td>
<td>1d</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Not answered</td>
<td></td>
<td>1d</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Several errors</td>
<td></td>
<td>3 + 1d</td>
<td>6 + 1d</td>
<td>4</td>
</tr>
<tr>
<td>Noticed cos (π) is a constant but made other errors</td>
<td></td>
<td>1 + 1d</td>
<td>1d</td>
<td>1</td>
</tr>
<tr>
<td>Integrated correctly but failed to find average value</td>
<td></td>
<td>1d</td>
<td>0</td>
<td>1d</td>
</tr>
<tr>
<td>Error at putting in limits</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Intermediate working undertaken to only 2 d.p.</td>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2 Correct</td>
<td></td>
<td>1d</td>
<td>1d</td>
<td>0</td>
</tr>
<tr>
<td>Not answered</td>
<td></td>
<td>1d</td>
<td>2</td>
<td>1d</td>
</tr>
<tr>
<td>Several errors</td>
<td></td>
<td>4 + 4d</td>
<td>6 + 1d</td>
<td>9</td>
</tr>
<tr>
<td>3 Correct</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Not answered</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1d</td>
</tr>
<tr>
<td>Several errors</td>
<td></td>
<td>4 + 4d</td>
<td>5 + 2d</td>
<td>4</td>
</tr>
<tr>
<td>Split integral but forgot to take modulus at the end</td>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Correct up to inputting values into calculator</td>
<td></td>
<td>1d</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4 Correct</td>
<td></td>
<td>5 + 2d</td>
<td>6 + 2d</td>
<td>7 + 1d</td>
</tr>
<tr>
<td>Not answered</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Several errors</td>
<td></td>
<td>1d</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Upper limit incorrectly transcribed as 2.0001</td>
<td></td>
<td>1d</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rounding error</td>
<td></td>
<td>1d</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5 Correct</td>
<td></td>
<td>1 + 1d</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Not answered</td>
<td></td>
<td>3 + 1d</td>
<td>1 + 1d</td>
<td>2 + 1d</td>
</tr>
<tr>
<td>Several errors</td>
<td></td>
<td>1 + 3d</td>
<td>4 + 1d</td>
<td>3</td>
</tr>
<tr>
<td>Error at putting in limits</td>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 33: Analysis of Students’ Paper Based Working

<table>
<thead>
<tr>
<th>Question</th>
<th>Version 1 Number of students</th>
<th>Version 2 Number of students</th>
<th>Version 3 Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>2 + 1d</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4 + 4d</td>
<td>5 + 2d</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 34: Number who Failed to Recognise cos(π) is a Constant (question 1) and Failed to Split the Integral (question 3)

Investigation of transcription errors, either from computer to paper or from line to line during calculation, did not show that dyslexic students were experiencing difficulty with this. One dyslexic student participating in Version 1 incorrectly transcribed the upper limit for question 4 as 2.0001 rather than 2.001. One non-dyslexic student participating in Version 3 omitted the modulus sign near the end of the calculation for question 3.
Manual marking of the scripts was then undertaken, with half the available marks being awarded for answers where the correct method had been employed but a minor error made. There were 28 occasions when this occurred. The average score obtained for each of the three versions was then recalculated and is shown in Table 35.

<table>
<thead>
<tr>
<th>Version</th>
<th>Average score from CAA</th>
<th>Average score from manual marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.3%</td>
<td>25.6%</td>
</tr>
<tr>
<td>2</td>
<td>22.9%</td>
<td>34.3%</td>
</tr>
<tr>
<td>3</td>
<td>32.7%</td>
<td>44.9%</td>
</tr>
</tbody>
</table>

Table 35: Average Score from Manual Marking of the Scripts

8.8 Personal Details and Information from the Questionnaires

Of the 30 participants, 27 had a GCE A Level Mathematics qualification, one had an International Baccalaureate, one had GCSE Mathematics and one had Scottish Ordinary Level as their highest mathematics qualification. All participants were between 18 and 23 years of age.

Students were asked whether they felt that CAA gave a realistic indication of their ability. Of the 30 students, 20 did not feel this was true. Comments from 21 students referred to the marking of CAA as being unfair as marks are not awarded for using the correct method with the result that a small mistake at the end of the calculation or a rounding error results in zero marks.

Students were also asked to indicate how many times, on average, in previous tests they referred to each displayed question. There was no difference between the answers obtained from students in each version, with the average number of times being 3. Students undertaking Version 1 and Version 2 were asked how many time they referred to each question and students undertaking Version 3 were asked how many time they listened to each question in this study. Students undertaking Version 1 and Version 2 referred to each question on average 3 times, the same as in previous tests. Students in Version 3 were asked to state how many times they listened to each question; on average this was once only.
Whilst there does not appear to be any evidence to suggest that the addition of diagrams or audio aided the students' performance, comments received from the students indicated that they were in favour of this representation. Three of the students participating in Version 1 expressed the opinion that they would like diagrams to be included in the questions. Of the students who participated in Version 2, eight were of the opinion that the addition of diagrams had aided their performance, one was unsure and one did not respond. There were two negative comments, one student felt that the diagrams were not very useful and another student was of the opinion that the diagrams made things look more complicated. Of the students who participated in Version 3, eight were of the opinion that the audio presentation had aided their performance, one believed that it had impaired their performance and one did not respond. One student made a negative comment that the voice was off putting. A suggestion from one of the dyslexic students was that key words, such as mean value, should be presented in bold font.

8.9 Discussion

Whilst this is only an exploratory study, the results do not suggest that dyslexic students are disadvantaged by CAA or that the different media combinations had a significant effect on the scores obtained or the time taken to complete the test. However, when method marks were awarded, most of the students obtained a higher score. What does need to be considered is that in this study, which was supervised, it was difficult for any form of cheating to take place. On the other hand in CAA undertaken as part of the module assessment process students may be helping each other and therefore the results obtained may not be giving a realistic indication of individual mathematical ability.

Two thirds of the participating students considered CAA of mathematics did not give a realistic indication of their mathematical ability due to marks not being awarded for method. The manual marking determined that there were 28 incidences where students received zero marks for questions where the correct method had been employed but a minor error made. Whilst there was not any evidence to show that the addition of a graphical representation or audio improved performance, 80% of the students participating in Versions 2 and 3 were of the opinion that it had aided their performance.
As the results of this exploratory study are in disagreement with those obtained by Beacham, Szumko and Alty (2003) the implication is that a much larger scale study needs to be undertaken before conclusions can be drawn. However, this exploratory study has laid the foundations for such a study, showing the need for serious consideration of the material to be included and the need for participants to have a similar mathematical background. A larger study could also consider the performances of individual participants across a range of different forms of testing such as coursework, multiple-choice examinations, written examinations and CAA.
In the academic year 2003/2004, during the first year of this research, it was decided to
investigate the current situation regarding the provision of mathematics learning support
in UK universities. The aims of this study were to determine the number of universities
offering support, the type of support available and if the support was spread evenly
between universities with differing backgrounds. This research was conducted solely in
the university sector of HE in the UK, with 106 institutions identified for the study

Visits to five universities, who offered mathematics learning support, were then made
during the academic year 2004/2005. These visits were undertaken to obtain a more
detailed insight into the range and level of support that was available in each institution.
Additionally, by viewing the different working environments that had evolved and been
developed by individual institutions, it was hoped to collect ideas which could be
implemented in the MLSC at Loughborough University to improve the facility.

During the academic year 2005/2006, an additional study was undertaken to determine
the number of institutions offering one-to-one mathematics support to dyslexic students
who had been awarded one hour of tutorial support per week and were experiencing
difficulties with the mathematical or statistical elements of their courses.

9.1 Introduction

From the review of literature that has been undertaken and reported on in Chapter II, it
is evident that there is indeed a ‘mathematics problem’. At Loughborough University
there are a growing number of students who are struggling to cope with the mathematics
and statistics in their courses and are seeking help from the MLSC. With the recent
reduction in the content of Mathematics GCE A Level the problem is not expected to
improve.
Another issue, which has compounded the ‘mathematics problem’, is the acceptance of students with lower grades than were previously required. In some cases students are being accepted without GCE A Level Mathematics on courses for which this had formerly been a prerequisite. This has occurred in departments, such as engineering, where there has been a reduction in applicants and a necessity to fill places. It is also expected that, as a result of the widening participation programme, institutions will see a significant increase in the number of students encountering difficulty with mathematics. This is in addition to an expected increase in the number of dyslexic students registered on courses.

With incoming students having less mathematical knowledge than was previously the case, support at the transition from school to undergraduate study is likely to become a necessity rather than a nicety.

This investigation into the current level of mathematics support in HE built upon an earlier LTSN-funded study, conducted in 2001, to determine the extent to which universities and FE institutions in the UK were providing mathematics support and to disseminate the findings. Lawson, Halpin and Croft (2001:19-23, 2002:23-26) established that 46 out of 95 responding institutions did provide support for mathematics, over and above that given by tutorials. They also highlighted that, deemed by the students, the provision of one-to-one support was the element found to be most helpful.

In the study that was undertaken for the research reported herein, 106 universities were contacted and 101 responses were obtained. From these responses 66 institutions offered some form of mathematics learning support in addition to that provided by tutorials, personal tutor groups and problem classes.

Of the universities that offered mathematics support the five that were subsequently visited all agreed to their institutions being referred to by name. These universities were: Coventry, De Montfort, Liverpool, Nottingham Trent and Sheffield Hallam.

As mentioned in Chapter I, since the introduction, in 2001, of individual mathematical and statistical support for dyslexic students at Loughborough University the number of
students in need of this support has increased. There is also growing awareness that problems being experienced by the dyslexic population continue into HE. New problems emerge at this level of study; greater demands, such as note taking and the requirement for independent learning in HE are proving to be catalysts for many students experiencing difficulties, seeking help and subsequently being diagnosed as dyslexic. With this growing awareness, and the need for universities to make reasonable adjustments to ensure that disabled students are not placed at a substantial disadvantage, compared to non-disabled students, it was considered that a valuable contribution to the knowledge base relating to support of dyslexic students in HE would be to determine how widespread this form of support is.

9.2 The Extent of Mathematics Learning Support in HE

This section explains the procedure for the survey, that was undertaken to determine the extent of mathematics support in HE, and details the forms of support that were found to be available.

9.2.1 Procedure for the Survey

From the website of the HEFCE, the Higher Education Funding Council for Wales (HEFCW), the Scottish Higher Education Funding Council (SHEFC) and the Department for Employers and Learning, Northern Ireland (DELNI), details of 106 universities were obtained (http://www.hefce.ac.uk/unicoll/HE/).

For the purposes of this investigation individual institutions have been classified into one of four categories: 'Russell Group', 'Red Brick' (traditional universities), 'Old' (pre-1992 universities) and 'New' (post-1992 universities) consisting mainly of the former polytechnics. Details of universities in the Russell Group were obtained from the internet (http://www.hero.ac.uk/reference_resources/russell_group3706.cfm). Whilst it might be argued that some institutions should be categorised as 'Ancient', this was decided against. Anonymity of individual institutions had been guaranteed and it was
believed that this might be compromised by the inclusion of a category containing only a small number of universities.

Prior to contacting any of the universities, a preliminary task was to identify, from the web site of each institution, whether or not there existed evidence of the provision of mathematical support. From each university, where support was found to be in existence, a contact name, email address and details of the support available, when provided, was recorded.

Universities that displayed evidence of learning support but without details of its provision or those that did not display any evidence of learning support were contacted by email with a request for information. A copy of this email is included in Appendix E.

In the cases where a university website had displayed evidence of learning support and a contact name, but without details of the level of provision, this person was contacted. For the remaining institutions the policy, regarding whom to contact, was as follows: if the university had a Mathematics Department then the Head of this Department was contacted. In the cases where universities did not have a Mathematics Department, the person contacted was the Head of Engineering, the Head of the Business School or the Head of Computing. In a few cases, where individual staff within departments could not be identified, information was sought from academic staff, in centrally-provided services, such as study skills tutors.

For the universities from which a response was not received, another department (if applicable) or member of staff was then contacted and if this failed to elicit a response, a third department (if applicable) or member of staff was then selected. There were a small number of universities who failed to respond to the emails; these were then contacted by telephone.

9.2.2 Response Levels by University Category

The 106 institutions that were included in this research comprised of 19 'Russell Group', 16 'Red Brick', 23 'Old' and 48 'New' universities. The number of responses
received, from each category, is shown in Table 36. An extremely high response rate of 95.3% was obtained from this survey and whilst this does not present a complete picture of the existence of learning support and the details of its provision in the UK, it may be deemed to be highly indicative of the situation in 2003/2004.

<table>
<thead>
<tr>
<th>Russell Group</th>
<th>Red Brick</th>
<th>Old</th>
<th>New</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>19</td>
<td>16</td>
<td>23</td>
<td>48</td>
</tr>
<tr>
<td>Responses</td>
<td>19</td>
<td>15</td>
<td>23</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 36: Mathematics Learning Support – response levels by university category

9.2.3 Results of the Survey

Of the 101 universities that responded to this survey, 65.3% have been found to offer some form of learning support for mathematics in addition to that provided by tutorials, personal tutor groups and problem classes and 34.7% do not offer any additional form of mathematics learning support. Five of the universities that were contacted (4.7%) did not respond. The results, by university category, are shown in Table 37.

<table>
<thead>
<tr>
<th>Russell Group</th>
<th>Red Brick</th>
<th>Old</th>
<th>New</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>19</td>
<td>16</td>
<td>23</td>
<td>48</td>
</tr>
<tr>
<td>Have Learning Support</td>
<td>11</td>
<td>8</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>Do Not Have Learning Support</td>
<td>8</td>
<td>7</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Did Not Respond</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 37: Availability of Mathematics Learning Support - numbers by university category

Where universities do offer support, it ranges from second/third year undergraduates providing drop-in support for first year undergraduates at limited but specified times, to fully-staffed and resourced Mathematics Learning Support Centres. Some universities,
which offer mathematics support, do not have a Mathematics Department and conversely some universities without any form of mathematics support do have a Mathematics Department.

Where Learning Support Centres do exist, they can be found in various locations and in many different guises. For example, some are located within Mathematics Departments, some within Engineering Departments, others are in centrally-located areas such as libraries or incorporated into a study skills or student support centre.

9.2.4 Details by University Category

Responses were received from all the ‘Russell Group’ universities with 57.9% of them offering some form of learning support. Only one of the ‘Red Brick’ universities failed to respond, which accounts for 6.3% of this category; of the respondents, learning support is offered by 53.3% of this group. All of the ‘Old’ universities responded with 52.2% of them offering learning support. The single largest category was that of the ‘New’ universities, the nil responses accounted for 8.3% and learning support was offered by 79.5% of the responding institutions.

9.2.4.1 ‘Russell Group’ Universities

The responses received from this category, confirming the existence of mathematics learning support, include one university, which offers support for basic mathematics only, and another, which currently offers peer-assisted learning but is planning to open a Resource Centre. The provision of support ranged from peer-assisted learning to dedicated mathematics learning support centres. Three of the universities detailed the provision of learning support on their web sites. Particulars of the form of support that is available and the number(s) of universities offering it are shown in Table 38.
Table 38: Mathematics Learning Support in the ‘Russell Group’ Universities

Of the universities in this category not offering mathematics learning support, the comments received included:

This is one area – the difficulty of the interface between school and university in mathematics – we are giving serious consideration to at present.

The provision of learning support is under active consideration.

Interestingly, one university, which did not offer learning support, split a first year mathematics module into 3 sessions. These were timetabled to allow the students, if they so wished, to attend all three sessions thus permitting a repetition of the material that had been covered.

9.2.4.2 ‘Red Brick’ Universities

The support on offer at the ‘Red Brick’ universities ranged from lecturers being timetabled for one-to-one support for about seven hours per week spread over four days to dedicated Learning Support Centres. Only one of the universities in this category detailed the provision of learning support on their web site. Particulars of the form of support that is available and the number(s) of universities offering it are shown in Table 39.
Table 39: Mathematics Learning Support in the ‘Red Brick’ Universities

Of the universities in this category not offering mathematics learning support, one university explained, “we are primarily a liberal arts institution” and another replied, “it [mathematics support] is not needed”. Other comments received included:

We would like to develop a Learning Resource Centre/ Drop-in Centre in the future, depending on the resources which become available.

There is definitely a need to offer many of our students additional help.

9.2.4.3 ‘Old’ Universities

The ‘Old’ universities offered support, which ranged from postgraduates employed as student support assistants to dedicated Learning Support Centres. Seven of these universities detailed the provision of learning support on their web site, although one, which advertised drop-in sessions, no longer provides this facility. Particulars of the form of support that is available and the number(s) of universities offering it are shown in Table 40.

Of the universities in this category not offering mathematics learning support, one used to have a drop-in centre but it has now closed. Other comments received included:

Drop-in sessions for 1-2 hours per week are about to be introduced.
We are looking to implement peer support up to GCSE level.

Another university relies on a local Community College, where, for a nominal fee, students may attend their mathematics drop-in workshops.

<table>
<thead>
<tr>
<th>‘Old’ Universities</th>
<th>Number offering support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning support/ drop-in centre</td>
<td>7</td>
</tr>
<tr>
<td>Maths clinic – two days per week</td>
<td>1</td>
</tr>
<tr>
<td>Twice weekly drop-in</td>
<td>2</td>
</tr>
<tr>
<td>Learning support tutor, primarily for maths modules</td>
<td>1</td>
</tr>
<tr>
<td>Student support assistants</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 40: Mathematics Learning Support in the ‘Old’ Universities

9.2.4.4 ‘New’ Universities

Included in the data for the universities in this category, who offer learning support, are one offering basic mathematics support and another offering numeracy support. The support available ranged from the aforementioned numeracy support to dedicated Mathematics Learning Support Centres. One university, which offers a mathematics surgery in the form of drop-in sessions of around 10 hours per week is considering the provision of a Learning Support Centre for mathematics and statistics, but has not yet gained central funding to enable provision of this resource. Nineteen of these universities detailed the provision of learning support on their web site. Particulars of the form of support that is available and the number(s) of universities offering it are shown in Table 41.

Regarding the universities in this category not offering mathematics learning support, at least one does not have any mathematics courses and another no longer has any mathematics modules. Other comments received included:
A properly managed and permanent mathematics clinic should be offered, given the weak mathematical backgrounds of many of our students, however, the problem is how to fund such a service.

It has been requested but there is a resource issue.

None planned but we are aware of the need.

<table>
<thead>
<tr>
<th>'New' Universities</th>
<th>Number offering support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning support/ drop-in centre</td>
<td>25</td>
</tr>
<tr>
<td>Maths clinic drop-in with limited hours</td>
<td>4</td>
</tr>
<tr>
<td>Numeracy support</td>
<td>3</td>
</tr>
<tr>
<td>Learning support tutor</td>
<td>2</td>
</tr>
<tr>
<td>Postgraduate support</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 41: Mathematics Learning Support in the 'New' Universities

9.3 Visits to Universities Offering Mathematics Support

This section details the results of interviews that were conducted at Coventry, De Montfort, Liverpool, Nottingham Trent and Sheffield Hallam Universities. The interview questions, which are included in Appendix E, were formulated to determine when each centre was opened, what prompted its opening, funding, opening hours, facilities, staffing, usage and if any specific help is available for dyslexic students. In January 2005, the MEC at Loughborough University in conjunction with Coventry University was designated as a Centre for Excellence in Teaching and Learning by the HEFCE. It was considered important that observations of useful and interesting ideas, and innovative practice should also be recorded. These observations along with the ideas for improvement and suggestions for change, that were obtained from the staff census forms and student questionnaires distributed within Loughborough University (see Chapter X), would help to shape the new Centre that is planned to open in October 2006 at Loughborough University.
Each of the following sub sections commences with an historical overview of the centre that was visited. It continues with a description of the then current facilities and details of additional provision that the institution would like to implement. Finally, the observations made by the author of this thesis are included.

9.3.1 Mathematics Support at Coventry University

This section contains details of an interview with Dr Glynn Smith recorded during a visit to the Mathematics Support Centre at Coventry University on the 11\textsuperscript{th} February 2005.

British Petroleum (BP) who sponsored courses at Coventry University were concerned about the retention of students. It was also perceived, within Coventry University, that many students were struggling with the mathematical elements of their courses. In 1991 The BP Centre, part funded by BP for a few years, was opened. The Centre was initially for first year engineering students and offered one-to-one support, on a drop-in basis, to these students undertaking specific mathematics and statistics modules. The BP Centre was open on a daily basis, for limited hours, with a small number of staff directly involved with it. There was a steady development of worksheets for individual topics and these were made freely available to students using the Centre. At this time the Centre did not have any computing facilities available for student use.

The BP Centre, now known as The Mathematics Support Centre, is part centrally funded and the School of Engineering contributes by timetabling staff to work in it. The Centre is open on weekdays with extended opening on Mondays until 19:00 and is staffed by mathematicians, statisticians and two postgraduate students with some members of staff able to offer help with ‘Maple’ and ‘Matlab’. The times for specific help are clearly indicated on the staffing timetable. The Centre also opens during Easter and September to allow those students who need to resit examinations to avail themselves of the service. Students are requested to sign in when using the Centre to enable the monitoring of usage levels. The students’ opinions on the Centre are also sought through the distribution of questionnaires.
Facilities now encompass several computers, textbooks and a whiteboard, which is sometimes used by the member of staff on duty if a group of students require help with the same problem or topic. There are a vast number of worksheets available, each giving fully-worked examples of a particular topic followed by some questions for which the answers are given. The worksheets are prominently displayed in racks around the room and are colour-coded to enable easy location of the mathematical topic being sought; for example, trigonometric worksheets are printed on green paper and statistics worksheets on yellow paper. The worksheets cover a range of topics from basic algebra to calculus. For nursing students there are samples of syringes and drips to give visual clarification of the size related to specific volumes. The Centre is open to everyone within the university and it has its own web site (http://www.mis.coventry.ac.uk/maths_centre/index.html).

Dr. Smith believes that whilst students at Coventry University are offered a high level of mathematics support there is room for improvement; however, there are financial constraints, which limit the amount of new endeavours that can be undertaken. He would like to introduce module-specific worksheets for material taught by the Mathematics Department, past examination papers with model solutions, more set textbooks, worksheets for additional topics and printing facilities, and if funding was available, interactive links and a remote centre with staff. Additionally, he would like to improve the staffing ratio, provide additional statistics help, particularly with data analysis, extend the opening hours of the Centre and the length of time during university vacations when it is open. He believes that the quality and depth of the worksheets could be improved upon and also feels that it is important to gain expertise from other universities that offer mathematics support and use this to update the facilities that are available at Coventry.

There has been a significant increase in the number of students using the Centre and this was most apparent when usage was no longer restricted to first year engineers. One concern about the increased usage is that the room is not very large and some students may be discouraged from using the Centre, as they may have to wait some time before receiving any help. However, there has also been an observed change in student attitude over the years with many students, who have been identified by diagnostic testing as being in need of help, failing to visit the Centre.
At the time of this visit the Centre did not provide any specific mathematics support for dyslexic students. Dr Smith did not feel that he had adequate knowledge of dyslexia to determine whether such support was needed but added that if students had been receiving additional or specialised support during their school years they may, quite reasonably, expect this support to be available in HE. Since the time of the interview the university has now appointed a member of staff who is directly responsible for providing one-to-one mathematics support to dyslexic students.

The Centre was observed to be friendly and welcoming and the colour coding that was used for the worksheets was viewed as being particularly useful.

9.3.2 Mathematics Support at De Montfort University

This section contains details of an interview with Ms Frances Wright recorded during a visit to the Maths Learning Centre at De Montfort University on the 16th March 2005.

It was Dr. Tony Croft who was responsible for the introduction of mathematics support at De Montfort University. The idea for introducing support came from a colleague of Dr. Croft. This colleague had been working in America for one year and returned with the idea of implementing some form of mathematics support such as that which was readily available in American institutions.

The Maths Learning Centre was initially located in the library and mentioned in support literature although there was no reference to its existence on the university web site. With the closure of the Mathematics Department funding for the Centre was withdrawn. However, a member of staff was subsequently recruited to offer help with mathematics up to GCSE level. The Student Learning Advisory Service was formed in 2000 and the Maths Learning Support Centre was moved from the library to a room dedicated for its use. It is now centrally funded. All staff who work in the Centre are qualified teachers. Staff development within the Centre is also being undertaken with workshops to improve the pedagogical skills of lecturers being organised. Members of Staff from the Maths Learning Centre are working closely with Engineering lecturers, who deliver mathematics modules, to gain details of the syllabus. With this detailed knowledge the
Centre is providing additional optional timetabled workshops. Support sessions for the statistical elements of courses in both the Business School and Psychology are provided, and additionally for the drug calculations needed by nurses.

The Centre now employs four members of staff who are specialised in different fields: one statistician, one engineer, one mathematician and one learning skills specialist. These members of staff generally work from the students' notes and the problems they bring to the Centre. The Centre seats 16 people and also houses three members of staff who will use their computers to print off material for students if this is required. The Centre is open from 12:30 - 14:30 daily, however, the finishing time is not set in stone and staff will continue past closing time if they are with a student who still needs some help. There are example sheets available and anyone from within the university may use the Centre. It has been used, not only by undergraduates but also by employees of the university seeking help with their children's school mathematics, postgraduates, and, on occasions, students from the University of Leicester have been found seeking help in it.

Ms. Wright feels that the Centre provides a valuable service but extended opening hours with lengthier one-to-one support sessions is required as this is the form of help that students need most. There has been a noticeable ongoing increase, during the last five years, in the number of students seeking help with mathematics; therefore it would be advantageous if a larger room, with a quiet work area, could be provided. With longer opening hours and more staff it may be possible to encourage students to become more responsible for their own learning; many students just come to the Centre to obtain the solution to a particular problem. To enable usage of the Centre to be monitored all students are required to sign in and give their name, faculty, and also comment on the help that they have received. In practice, the comments section fails to be informative, for example, if the comment recorded on the top line is 'good' students tend to copy this for the remainder of the page.

The Centre does not provide any specific mathematics support for students with dyslexia. One member of staff offers a limited number of one-to-one support sessions of 30 - 60 minutes duration to students who frequently use the Centre and are seen to be in need of more than drop-in support. Ms. Wright feels that one-to-one support sessions should be made available to all students in need of them.
All new students, during their first year induction period, undertake a Key Skills Analysis Test, which is self-marked and assessed. The students who perform poorly are encouraged to seek help with their mathematics but, in practice, this rarely happens.

The Centre was observed to be warm and friendly, a particularly nice gesture was that students who had been working for a long time were offered a cup of coffee. The room had an inhabited atmosphere, and on a table near the door there was bottled water, glasses and tissues. Plants and posters also contributed to the homely environment. A useful list of the library location of mathematical texts was also prominently displayed. The wording from two of the posters is appended in Figures 17 and 18.

A Different Kind of Library

You can use these desks as a place to sit and work

Like a library with a difference

In a library you would need to look for a book if you got stuck

Here you can ask one of us

Figure 17: Text Taken from a Poster Entitled ‘A Different Kind of Library’ displayed in De Montfort University Maths Support Centre

CHEATING

Working together isn’t CHEATING.

Using a calculator isn’t CHEATING.

Finding the answer from the back of the book and trying to work out how they got it isn’t CHEATING.

CHEATING is pretending you understand when you don’t.

That’s when you are CHEATING yourself.

Figure 18: Text Taken from a Poster Entitled ‘Cheating’ displayed in De Montfort University Maths Support Centre
9.3.3 Mathematics Support at the University of Liverpool

At the time of the survey that was undertaken to determine the extent of the provision of mathematics learning support in UK universities, the University of Liverpool responded that it offered peer-assisted learning and also planned to open a Resource Centre. This section contains details of interviews with Professor Irving, Head of Mathematics, Professor Giblin and Dr Toby Hall that were recorded during a visit to the Mathematics Resource Centre at the University of Liverpool on the 2\(^{nd}\) June 2005.

Professor Giblin had the idea that he would like third and fourth year undergraduate and postgraduate students to be available to support first year students with their mathematics. He believed that this would not only help first year students with any difficulties that they were encountering, but would also result in the students offering the support gaining a greater understanding of topics they had already encountered. This drop-in peer support has been running for five years and has proved to be popular and well attended. There are six students each timetabled for one to two hours per week and the service is well advertised.

The Resource Centre was opened in 2004 in response to suggestions made by the staff/student committee. There was a refurbishment plan taking place and students in the department had been asked to suggest facilities that they would like to have. It is funded by the Mathematics Department and a refurbishment project and has replaced the Maths Reading Room, which had been located in a different building. The Centre is comprised of two rooms that are separated by sliding doors. One room is filled with computers and contains student pigeonholes. The other room contains tables and chairs, textbooks, blackboard, internal phone, careers board and notice boards for use by the students. There is also a photocopier with a pay slot that has been provided by the Mathematics Department and is looked after by the students. Students are allowed to eat and drink in this room and a small kitchen is located outside it containing a microwave, vending machine and kettle. The Centre is open from 09:00 - 17:00 on weekdays during term time and may be used by anyone; however, it is only mathematics students who are notified of its existence. Students were initially concerned that the textbooks might go missing and the kitchen would be left in a mess, however, these concerns have proved to be unfounded.
During the first month of the Centre’s existence it was patronised by few students but its popularity has grown and it is now extremely busy and on many occasions full.

It is believed that the service provided is adequate for the needs of the students. However, it is often the students who are most in need of help that do not avail themselves of it. Dr. Hall feels that the provision of extra textbooks would be a useful addition to the Centre. Professor Giblin would like past examination papers and solutions to be made available and the peer support to be re-located to the Centre. Furthermore, he would like students from other departments, with a mathematical content, to be made aware of the Centre. Professor Irving feels that many engineering students are in need of additional support with the mathematical elements of their courses.

Dyslexic students are provided with additional printed notes from their lecturers but there is not any specific mathematics support available for them.

In the past, tutors had been timetabled to help weak students and diagnostic testing had been administered sporadically. For two years the Coventry University diagnostic test was given to those students undertaking courses with a high mathematical content. Students who performed poorly were offered additional classes, but attendance was disappointing - only one student was present during the second year of this support. During the 2004/2005 academic year additional classes were offered to some students on the basis of their incoming grades. No-one attended these classes after the first week.

The Resource Centre had a warm and lived-in feeling, the student notice boards contained photographs of student social functions and the photocopier and kitchen were observed to be very useful.

9.3.4 Mathematics Support at Nottingham Trent University

This section contains details of an interview with Mrs Sarah Woodhouse recorded during a visit to the Maths Support Centre at Nottingham Trent University on the 20th May 2005.
It was recognised within the Faculty of Computing, Construction and Technology that many of their students needed support with the mathematical content of their courses. The Centre was opened in September 2003 using Widening Participation funding. It was in danger of being closed in June 2005, however, this was reconsidered and the Centre is to remain open.

The Centre is housed in the City Campus in a large room and initially contained two computers, printed leaflets from mathcentre, algebra and calculus refresher booklets, blackboards, a large notice board advertising the mathematics support that is available and a small number of textbooks. The Centre was initially for use by students from Computing, Construction and Technology and was used by them as a place to work as well as to obtain help. The computers were seldom used and there was not any support available to assist with the use of computer packages. Whilst the blackboards are only used infrequently, they have been useful on the occasions when a group of students have arrived with the same problem.

Due to the source of funding, support is primarily aimed at the weaker students; however, the Centre is now open to students from all departments except those undertaking mathematics degrees. The Centre is open on Tuesdays to Thursdays from 10:00 – 16:00 and on Friday from 10:00 – 14:00. On Wednesday morning it is open for use by students from Social Sciences on an appointment only basis. Support is also offered at the Clifton Campus on Mondays by appointment only. It is the Centre at the City Campus that is in the most demand. The support is provided by a mathematics academic.

Diagnostic testing is used for those students who will encounter mathematics modules. During the academic year 2003/2004 a mentoring scheme was introduced to support engineering students who had been identified as ‘weak’ by the diagnostic test; second year mathematics students were employed to assist groups of these students. Unfortunately, the students deemed to be in need of additional support did not use this support. Mrs Woodhouse also targeted these students by letter, email, and through their lectures, but was unsuccessful in persuading the students to come for help. With the closure of the Mechanical Engineering course widespread diagnostic testing is no longer taking place, although Civil Engineering intends to continue this practice.
In an attempt to attract more students, especially those most in need of help, specific courses, where students have been known to have difficulties, were targeted rather than individual students who had been identified by the diagnostic testing. This approach appears to have been successful; there has been a 30% increase in usage from the academic year 2003/2004, however, it must be taken into account that the Centre is now open to more students than was previously the case. During the academic year 2004/2005, at the time of the author’s visit, there had been 530 visits, and the expectation was that the total would be approximately 570 compared to 427 in the previous year. Regular attendees account for 60% of this total. The students are not asked to sign in as it was considered that they might find this daunting, instead of this a record of attendance, which includes the student’s name, year of study, course and dates of visits is maintained by Mrs Woodhouse.

Mrs Woodhouse feels that the Centre does provide adequate help for the needs of the students, although more textbooks would be a welcome addition. She attends courses and takes an active interest in GCE A Level Mathematics syllabi. She would like to provide some additional facilities, such as special sessions during induction week, timetabled sessions covering basic topics and have a stringent testing system in place that would alert students to the fact that they are in need of help.

There is not any specific provision of mathematics support for dyslexic students, although Learning Support Services have referred some dyslexic students to the Centre. Mrs Woodhouse assisted these students and found that each of them had different difficulties. She is unsure of the numbers that might be involved so was not able to comment on whether there is a need to introduce any specific support for these students.

The Maths Support Centre is housed in a large pleasant room on the sixth floor. It has huge windows giving not only adequate natural light but also a wonderful view over the rooftops of the city centre.
9.3.5 Mathematics Support at Sheffield Hallam University

This section contains details of discussions with Dr Neil Challis and Mrs Liz Thompson recorded during a visit to the Maths Help Centre at Sheffield Hallam University on the 17th May 2005.

Maths Help was opened in 1991 offering drop-in mathematics support and it is believed that this was the first enterprise of its kind within UK HE institutions. It was introduced in response to the large number of students, on mathematics courses, who were in need of support additional to that which was provided in timetabled tutorial sessions. Initially it was only available for about two hours per week and was Central University funded through the Curriculum Initiative Fund. Subsequently Enterprise Funding was obtained and Maths Help became available for ten hours per week. It now receives Widening Participation Funding and is also subsidised by the Mathematics Department. The amount of support that is provided is currently being reviewed.

Maths Help is located in the library (not in a quiet area) and is open daily from 11:30 - 13:30 during teaching weeks, revision weeks and examination periods. There is a large table surrounded on two sides by shelves containing mathematics, physics and engineering texts, another side contains computers, and a cupboard containing some help sheets, which has resulted in a secluded area. Toilets are located nearby. Students are asked to sign in but nervous students are not pressurised to do so; it is estimated that about 70% of the students attending do sign in. Usage of Maths Help varies from year to year, however, during this academic year (2004/2005) there has been a noticeable reduction in the number of students attending. This has been attributed to the cessation of the Physics degree. Maths Help is staffed by two academics, one from the Mathematics Department and one from Computing Studies, both of whom appear to be friendly and approachable, and able to offer help with a wide range of topics. Mrs Thompson is conversant with all GCSE, GCE A Level mathematics syllabi and also Oxbridge entrance examinations. Any Sheffield Hallam student may use the support, students from other universities have turned up occasionally and been given help provided there was time available to do so. Members of staff with children at school have also used Maths Help to obtain help and advice with GCSE Mathematics.
Diagnostic testing is given to engineering and mathematics students during induction week. Mrs Thompson is given the results from this testing and individual lecturers recommend students to attend Maths Help. In addition to Maths Help, Sheffield Hallam also offer a course, which is funded both centrally and by student services, entitled Maths for the Terrified; this has an equivalent number of hours to a 10 Credit module and students may take an assessment that is equivalent to the Maths Workshop module which is undertaken by biomedical science students.

At Sheffield Hallam University there is not any specific mathematics support for students with dyslexia but Learning Support Services direct dyslexic students, who are having difficulties with their mathematics, to Maths Help. Mrs Thompson now sees several dyslexic students who attend regularly and she uses a diagrammatic approach when helping these students. She feels that there is a need to introduce specific help for these students that will enable sufficient time to be spent with each individual.

Mrs Thompson is of the opinion that the opening hours are suitable for most students and those attending are helped with their difficulties. However, there are some students who can only attend on or after 17:00. Therefore, one or two later sessions would be of benefit to these students. It is the personal one-to-one help that the students require and to minimise waiting time additional staffing is required.

The working area of Maths Help is dominated by an impressive ‘curly’ table, which is partially enclosed by relevant textbooks giving privacy to the area.

9.4 Mathematics Support for Dyslexic Students in HE

This section explains the procedure for the survey, that was undertaken to determine how widespread is the provision of one-to-one mathematics support to dyslexic students eligible for additional tutorial support, when their needs for such support are of a mathematical nature. It then details the extent of this provision.
9.4.1 Procedure for the Survey

The 66 universities that had been found to offer some form of mathematics learning support (section 9.2.3) were again contacted by email with a request for information. A copy of this email is included in Appendix E. There had, inevitably, during the two years since the earlier study, been staff changes in institutions and some of the contact details were no longer applicable. In these cases and in the cases of a response not being obtained the procedure, already outlined in section 9.2.1, was followed.

9.4.2 Response Levels by University Category

The 66 institutions included in this survey comprised of 11 ‘Russell Group’, eight ‘Red Brick’, 12 ‘Old’, and 35 ‘New’ universities. The number of responses received, from each category, is shown in Table 42.

<table>
<thead>
<tr>
<th>Russell Group</th>
<th>Red Brick</th>
<th>Old</th>
<th>New</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>11</td>
<td>8</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>Responses</td>
<td>8</td>
<td>7</td>
<td>11</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 42: One-to-One Mathematics Learning Support for Dyslexic Students – response levels by university category

A response rate of 77.3% was obtained from this survey, whilst this does not present a complete picture of the existence of one-to-one mathematics support for dyslexic students in the UK it may be deemed to be highly indicative of the current situation.

9.4.3 Results of the Survey

Of the 51 universities that responded to this survey, 25.5% have been found to offer specific one-to-one mathematics support to dyslexic students, 74.5% do not offer support of this nature. Of the 66 universities that were contacted 15 (22.7%) did not respond. The results, by university category, are shown in Table 43.
Where universities do offer one-to-one support to dyslexic students, it ranges from a dyslexia support tutor with a mathematics background, a mathematics tutor being available to specifically help dyslexic students, to staff being employed specifically to help such students.

### 9.4.4 Details by University Category

Responses were received from eight of the ‘Russell Group’ universities who were contacted, which accounts for 72.7% of this group, of the respondents one-to-one support for dyslexic students is offered by one (12.5%) of this group. Seven of the ‘Red Brick’ universities responded, which accounts for 87.5% of this group, of the respondents two (28.6%) offer this form of support. Eleven of the ‘Old’ universities responded, which accounts for 91.7% of this group, of the respondents two (18.2%) offer this form of support. The single largest category was that of the ‘New’ universities, responses were obtained from 71.4% of this group, of the respondents eight (32.0%) provided support.

<table>
<thead>
<tr>
<th>Number</th>
<th>Russell Group</th>
<th>Red Brick</th>
<th>Old</th>
<th>New</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide one-to-one mathematics support to students with dyslexia</td>
<td>11</td>
<td>8</td>
<td>12</td>
<td>35</td>
<td>66</td>
</tr>
<tr>
<td>Do not provide one-to-one mathematics support to students with dyslexia</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>17</td>
<td>38</td>
</tr>
<tr>
<td>Did Not Respond</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 43: Availability of One-to-One Mathematics Learning Support for Students with Dyslexia - numbers by university category
9.4.4.1 ‘Russell Group’ Universities

Only one university in this category offered one-to-one mathematics support to dyslexic students. This is provided by the dyslexia support tutor who has a mathematics background.

Of the universities in this category not offering such support, the comments received included:

We do not single out this group of students for special treatment.

The only thing that the disability service has requested is either a scribe, a reader or extra time for exams.

We offer absolutely no support for “dyslexic mathematicians”.

9.4.4.2 ‘Red Brick’ Universities

Only two universities in this category offered one-to-one mathematics support to dyslexic students. One university had recently introduced this support. The other provides one-to-one support when it is requested and also seeks guidance from their disability unit on how best to help dyslexic students.

Of the universities in this category not offering such support, the comments received included:

Any student who is dyslexic is advised to go to the University’s study support section who can give expert guidance and support, including specific areas where dyslexia causes our students problems in writing essays/projects.

In general we do not offer specialist mathematical help for dyslexic students. Instead, general study skills tutoring is available from the Educational Support Officer.
9.4.4.3 ‘Old’ Universities

Only two universities in this category offered one-to-one mathematics support to dyslexic students and in both cases it was of a regular timetabled nature.

Of the universities in this category not offering such support, the comments received included:

We have yet to encounter dyslexic students requiring specifically Maths support, although I did encounter a student requiring the use of a calculator in exams for simple arithmetic because he would often transfer numbers wrongly.

We don't have specific mathematics support for dyslexic students. I don't know why we haven’t thought of specific problems that maths students might have with regard to dyslexia.

The Mathematics Support Centre does not at present employ specialist staff capable of helping dyslexic students.

9.4.4.4 ‘New’ Universities

Of the eight universities who offer this form of support, five have dedicated staff who provide timetabled one-to-one support. Two universities have members of staff (a mathematics tutor or mathematics lecturer) who give mathematics support to students with special needs. Another university responded:

Tutors provide additional tutorial support for students with dyslexia. My view is that if this [time each week] was requested we would provide it. If a colleague refused I would make alternative arrangements for the support (or negotiate a timetable allowance for the colleague if that were reasonable). So I'm sure we would provide the support: but we've certainly (as far as I know) never been asked.

Of the universities in this category not offering such support, the comments received included:
We don't currently offer specially trained support to dyslexic mathematics students, although it is often these students who make good use of our daily 'maths/stats aid' drop-in sessions.

No we don't provide any special facilities over and above extra time etc., for assessment.

What interests me greatly is that these days fewer and fewer dyslexic students are asking for scribes/extra time in assessments. Perhaps students are identified earlier and cope better or teaching styles and exam questions have been changed which suit the dyslexic students better.

There were, amongst the universities not offering one-to-one mathematics support to dyslexic students at least two institutions that have mathematics learning support centres and had had students referred to them from their disabilities units. Mrs Woodhouse at Nottingham Trent University mentioned students who had been referred to her by the Learning Support Service and this was again found to be the case at Sheffield Hallam University. In both these institutions staff were trying to support the students, on a regular basis, to the best of their ability. At Loughborough University provision of this form of support was initiated in response to a request from a member of the ELSU. It is evident that members of support units recognise that there is a need for specialist mathematical support for dyslexic students.

9.5 Conclusion

Regarding mathematics support, it has been established that 65.3% of the responding universities have some form of learning support and 34.7% do not offer this facility. Five of the universities that were contacted (4.7%) did not respond. Additionally, a total of nine universities are about to open some form of mathematics support, would like to offer support or recognise a need to provide support. Just over 50% of the 'Russell Group', 'Red Brick' and 'Old' universities offer some form of mathematics support whereas almost 80% of the 'New' universities are offering this facility. It appears that an increasing number of universities are finding a need amongst their students for some form of mathematics support.
It is evident, as can be seen from above, that the situation regarding the provision of mathematics learning support is not static, however, every effort has been made to ensure that the data reported is accurate. The author of this thesis is of the belief that this portrays a largely accurate picture of the type and level of mathematics support provided by universities in the UK.

The examination of university web sites revealed that it was not always clear exactly where to look for evidence of learning support and in some cases it was not easy to locate. In many cases it was not obvious whom to contact and in one institution, two members of staff from the same department eventually replied, one claiming the existence of learning support and the other writing that no such provision existed. It is also believed that it would be useful to students and potential students if those institutions, which do provide mathematics learning support, could clearly identify this facility on their web site.

The visits to individual institutions have shown that there are significant differences in the choice of location and the provision of support. Furthermore, each of the institutions that were visited had introduced highly individual aspects to their support areas.

It has also been determined that the provision of one-to-one mathematics support to dyslexic students is not widespread. Many universities referred dyslexic students to their disability units. However, it is unlikely that many staff in these departments will have the expertise to help those students who are reading for a degree with a high mathematical content, with their mathematical difficulties. It appears that, for those dyslexic students who are experiencing difficulties with their mathematics, the support available is inconsistent between institutions and resembles a 'lottery'.
The MLSC at Loughborough University opened in 1996 in response to a change in, and disparity of, the mathematical knowledge of incoming students. This chapter reviews the inception of the MLSC and mathematical difficulties encountered by those using the MLSC as observed by the author of this thesis. A census form was distributed to members of staff in the School of Mathematics and a questionnaire was also distributed to students who frequently avail themselves of the facility. The census forms and questionnaires were designed to answer many more questions than are reported herein. It was considered that staff and students could not realistically be expected to complete more than one census/questionnaire in the foreseeable future. The distributed forms contained questions that appertained to the design of a new/refurbished Centre and other areas such as student experience and student satisfaction, which are currently topical issues but outside the scope of the current research. In addition to the extraneous information that was sought, the staff census and student questionnaires were designed to answer three questions. 'How effective is the MLSC?’, ‘How effective is the drop-in support for students with dyslexia?’ and ‘How necessary is the MLSC?’ The research design, which includes eight hypotheses, all the associated case study documentation and the census forms and questionnaires in their entirety may be viewed in Appendix F.

10.1 History of the Mathematics Learning Support Centre

A semi-structured interview was arranged with Mr. Geoff Simpson, a retired lecturer who had worked in the School of Mathematics at Loughborough University for 37 years. The support that had been offered by Mr. Simpson, in 1995, prior to the opening of the MLSC, had proved instrumental in establishing that there was, indeed, a need for mathematical support over and above that which was provided by tutorials and personal tutor groups. A subsequent interview was then held with Professor Clive Pugh, who had been the Head of Department at this time, in order to corroborate, or otherwise, the information that had been obtained from Mr. Simpson.
10.1.1 Interview with Mr. Geoff Simpson

When did you notice a need for support?
Over a period of time the engineering student cohort had changed from having a homogeneous mathematical knowledge to some disparity in knowledge. By the mid 1990’s there was a huge disparity of mathematical knowledge between students enrolled on the same course. It was becoming increasingly difficult to deliver the mathematical topics on modular syllabi to incoming students. Discussion with the Engineering Department had failed to obtain a reduction in the mathematical content of syllabi.

What sort of problems were you encountering?
The problems encountered were numerous. For example, students were having difficulty in finding the determinant of a 2x2 matrix without writing down every step; that is, they were unable to multiply two numbers together and hold this value in their minds whilst multiplying two other numbers together and then subtracting the second result from the first result. Another example is that of a Production Engineering student who failed her first year mathematics module, she was extremely upset and stated that she had never previously failed a mathematics examination. However, it transpired that her highest mathematical qualification, prior to entering university, was GCSE Grade D. Furthermore, problems were also compounded by the fact that the engineering mathematics modules contained a large number of students, typically over 150.

How did your provision of mathematics support evolve?
Professor Clive Pugh, the Head of Department, had talked about the need for some form of mathematics drop-in support and discussed ideas for the delivery of this support but nothing had actually been decided. I was not actively involved in research and enjoyed teaching, indeed, I had taught tens of thousands of students during my 37 years of lecturing at Loughborough University. I suggested to Professor Pugh that I make myself available on Wednesday afternoons, a time when there were not any timetabled lectures, and set myself up as a drop-in tutor. Posters designed by myself were placed in prominent positions around the campus and advertised that drop-in support was available in my office on Wednesday afternoons from 2.00pm until 5.00pm.
Unfortunately, none of the original posters have survived the passage of time, but they were worded as shown below:

D Difficulties
I In
M Mathematics
Tutor

What was the reaction of your colleagues to this support?
At this stage I did not encounter much active support from other academic staff in the department and did not receive any realistic timetable allowance for this venture. Some members of staff frowned upon the title of this support, DIM Tutor, saying that it implied that the students were dim. However, Professor Pugh expressed an interest in the number of students attending and realised that there would be sufficient clientele for a more formal Centre.

What were the reactions of the students to this support?
The student population found the title amusing and said that it encouraged them to avail themselves of the service.

What were the usage levels?
From initially a couple of students arriving on a Wednesday afternoon it rapidly grew to more than a dozen, which established the need for the provision of a more formal and dedicated service.

For how long did this support run?
Dim Tutor commenced in October 1995 and was available until the opening of the MLSC in October 1996.

Who could use DIM Tutor and what did it aim to do?
DIM Tutor was for any student experiencing problems with mathematics regardless of which faculty they belonged to. The idea of this support was to encourage students to overcome any difficulties they were having and my message to the students was not to
worry about dropping-in; the problem is either trivial and can be solved quickly and easily or it is a serious lack of understanding that definitely needs sorting out.

10.1.2 Interview with Professor Clive Pugh

Why was mathematics learning support introduced?
There had been a significant drop in the number of students wishing to study engineering; this had resulted in the recruitment of students with lower qualifications than those that had traditionally been held. Within the Mathematics Department there was an awareness and realisation of the money that service teaching brought into it. I needed to protect this service teaching and recognised that there were problems in getting students through their first year mathematics modules. Geoff Simpson, a lecturer in the Department, offered his services as a drop-in tutor, which I accepted. This support was available one afternoon per week and advertised by Geoff as DIM Tutor. There was division amongst academic staff in the department with some members of staff feeling that this support should not be needed. However, the number of students attending DIM Tutor clearly established that there was a need for mathematics support.

How was the Mathematics Learning Support Centre Funded?
In 1996, due to favourable funding, there was money available in the Faculty of Science and I convinced the Dean of the need to introduce Mathematics Learning Support. I was then responsible for obtaining money from both the Faculty of Engineering and the Mathematics Department to contribute towards the cost of introducing Mathematics Learning Support at Loughborough University. The MLSC was opened in October 1996.

10.2 The Mathematics Education Centre

In 2002, a decision was made to establish the MEC at Loughborough University, the aim of which is to provide the environment and expertise to ensure that each and every student maximises their mathematical abilities. The MEC provides service teaching, pre-sessional materials, diagnostic testing, follow-up support and tracking of those
students who are considered to require help. The MLSC is under the jurisdiction of the MEC. Another important area of responsibility of the MEC is that of materials development and dissemination (Croft and Robinson, 2003:7-8).

The HELM project funded for three years by a grant of £250,000 from the HEFCE through phase 4 of the Fund for the Development for Teaching and Learning (FDTL4) was commenced in October 2002. This project aimed to extend Loughborough University’s open learning materials and was undertaken in conjunction with the Universities of Hull, Reading, Manchester and Sunderland. The material consists of 50 student workbooks, Computer Assisted Learning (CAL) segments and a CAA regime. This material was tested at over 20 HE institutions during 2004–2005. It is now freely available to HE institutions via the World Wide Web (http://www.lboro.ac.uk/research/helm/).

10.3 Observations in the Mathematics Learning Support Centre

During the academic year 2003/2004, staff and students in the MLSC were observed. The help given by members of staff and the difficulties experienced by students have been recorded. There were a number of questions that were frequently asked, and difficulties that were frequently experienced, by both dyslexic and non-dyslexic students, which were related to their low level of prior mathematical knowledge. These observed difficulties provide evidence of the need to provide mathematical support to enable students from non-traditional backgrounds and students who are admitted with lower than previously required qualifications, in accordance with widening participation in HE, to read successfully for a degree with a mathematical component. These difficulties are presented in Section 10.3.1.

This two-semester period of observation also enabled a comparison to be made between the mathematical difficulties that were experienced by students using the Centre and the dyslexia-related difficulties that were observed during one-to-one support. It is appreciated that some students having difficulties with mathematics and attending the MLSC might also be dyslexic. However, as a result of the exploratory case studies, the provision of one-to-one support and by the undertaking of mathematics tutorials, the
author of this thesis is personally acquainted with many of the dyslexic students who are attending the MLSC. It is believed that most of the observed general mathematical difficulties, see section 10.3.2, were encountered by non-dyslexic students and differ significantly from those witnessed during the one-to-one support sessions. Isolated problems, which were encountered with particularly challenging tutorial questions, have not been included.

10.3.1 Difficulties Related to Prior Mathematical Knowledge

There were several questions, which were repeatedly asked by dyslexic and non-dyslexic students over the two-semester period of observation. These questions revealed an extremely worrying lack of elementary mathematical knowledge, which demonstrated that these students were inadequately prepared for the university-level mathematics they were encountering.

The questions posed most repeatedly were:

- What is a co-efficient?
- What does linear mean?
- What does Cartesian mean?
- What is a log – can I just press the log/ln button on my calculator, does it matter which one?
- Does it matter whether my calculator is in radians or degrees?

Additionally, there were other frequently encountered difficulties observed, which also demonstrated that many students had an extremely weak mathematical background that was hampering their attempts to solve problems on tutorial sheets.

Many students were unable to rearrange an equation and did not understand that subtracting a number from both sides of an equation was identical to moving a number from one side of the equation to the other and reversing the sign. Furthermore, if the equation involved fractional parts, many students were unable to rearrange such an equation as they did not understand the elementary procedures that were required such as obtaining a common denominator. Subsequently, algebraic fractions were a complete mystery to them as they were unable to compute numerical fractions. There was
frequent and disturbing evidence of students who could not multiply together two one-digit numbers without the use of a calculator and also total incomprehension of the relevance of positive and negative signs preceding numbers or algebraic expressions.

In particular, there were many difficulties observed in the field of calculus amongst those students who did not have any knowledge of this area of mathematics prior to commencing university. Whilst this particular topic is covered from first principles, in all degree courses at Loughborough University, the subject is covered quickly when compared to the time that would have spent on it at A Level. Students were attempting to complete questions on tutorial sheets containing natural logarithms yet were unable to differentiate simple polynomial expressions. Students were also trying to solve differential equations and Fourier analysis questions without being able to carry out competently the procedure of integration by parts.

Students were also unable to proceed with questions containing commonly used mathematical notation such as Σ as they had not previously encountered this or any other Greek characters other than π. They did not understand what the character Σ was mandating them to do. Additionally, many mistakes were made and much time wasted by students multiplying out expressions of the form \((3x + y)^6\) longhand as they were unacquainted with Pascal’s Triangle and its application.

What is also perturbing is that many students were not conversant with the process of long division and were therefore unable to perform algebraic division. For example, students encountering a question such as, ‘given the power four equation, \(x^4 - 11x^3 + 44x^2 - 76x + 48 = 0\) and the information that there is a double root at \(x = 2\), find the remaining two roots’, were often totally mystified and unable to proceed. Once it was explained that the original equation could be divided by \((x - 2)^2\) and the quadratic equation thus obtained could then be either factorised or solved, they were still unable to proceed, as they were not able to undertake long division or recognise that they could proceed by comparing the co-efficients.
10.3.2 General Mathematical Difficulties

Other difficulties witnessed in the MLSC involved inadequate understanding of the method being employed and were generally of a very different nature to those encountered during the one-to-one support of dyslexic students.

Most of the difficulties observed during one-to-one support of dyslexic students arose from one or more of the following:

- Experiencing visual disturbance resulting in difficulties with operations involving rows and columns of figures
- Incomplete or inaccurate lecture notes
- Extracting what is actually being asked when confronted with lengthy descriptive text
- Carrying out multi-stage mathematical procedures
- Incorrectly writing down the original question or making transcription errors
- Making mistakes when moving from line to line and/ or turning over a page.

Whereas the difficulties that were observed in the MLSC generally arose from:

- Students only having superficial knowledge of a topic leading to illogical practice
- Examples in lecture notes having less detail than was required by the students
- Misinterpretation of mathematical procedures
- Inability to formulate mathematical arguments.

An example of the first bullet point listed above is that of a student trying to obtain 1st, 2nd, and 3rd derivatives of the function \( y = e^{x}(1 - x)^{1} \). The first derivative she obtained was:

\[
\frac{dy}{dx} = e^{x}(1 - x)^{-2}
\]

When asked how she had arrived at the solution, she explained:
Well, I know that $e^x$ stays the same when it’s differentiated so I have treated it as a constant, therefore I didn’t have to use the product rule and this has saved me a lot of messy and lengthy calculation.

Maclaurin series frequently gave rise to misinterpretation of what was required. One commonly arising misunderstanding occurred when students were asked to find the series representation of functions such as $e^x\sin(x)$ from first principles. Many students obtained the series representations from their formulae booklets then multiplied them together; they were not aware that this was not from first principles. On other occasions students did work from first principles but demonstrated lack of understanding and undertook unnecessary computation. One example of this is a question that required the series representation of $(1+3x)^{-\ln(1 + 2x)}$ to be determined from first principles. The student found 1st, 2nd, 3rd and even 4th derivatives of the whole function using the product rule rather than finding separate series representations and then combining them at the end.

Another area of difficulty that was witnessed was that of formulating a mathematical argument. For example, students were often unable to commence questions that gave a description of a physical event and required the setting up of differential equations. Once the equations had been determined the students were able to proceed. It appears that many students are able to solve directly posed questions, but lack understanding of the application of mathematics.

10.3.3 Staff Working in the Mathematics Learning Support Centre

In general, the staff who were observed working in the MLSC were not only approachable, friendly and helpful but were also able to recognise instances where the reason why students were struggling was due to their misconceptions about the underlying mathematics or where they lacked the necessary algebraic fluency to enable them to deal with a particular question. Students, in these instances, were often helped with the mathematics that underpinned the work they were attempting and when the Centre was busy they were directed to resources that would help them. Regarding coursework, the majority of observed staff were supportive and referred students either
to a relevant section of their lecture notes or found a similar question in a textbook with which they then gave help.

On a less positive note there were a small number of occasions when the members of staff on duty were engrossed in their own work and failed to observe that a student or students were waiting for help. In these instances the students awaiting help just sat and waited and did not approach the lecturer themselves. It is considered imperative that all staff on duty in the MLSC should be pro-active in helping the students they are employed to help. There were also a minority of instances where staff made comments such as, “This is elementary” or “You should be able to do this”. All members of staff working in the Centre need to be made aware that some students may not have taken GCE A Level Mathematics and furthermore, several years may have elapsed since such students sat their GCSE examination. It is comments such as those previously quoted that might well deter the students most in need of help from attending the Centre. As mentioned in the previous paragraph, most members of staff were supportive when asked questions appertaining to coursework. Nevertheless, some students who pointed out that the question was coursework and explained that they did not know how to start the question were told, “I can’t help you, it’s your coursework”.

From these observations, it is recommended that all members of staff who work in the Centre should be conversant with the material that is covered in GCSE and GCE A Level Mathematics syllabi. Furthermore, it is considered that comprehensive guidelines should be provided to detail explicitly the help that may be provided in relationship to questions appertaining to coursework. Staff who work in the Centre must also be made aware that is their responsibility to be alert to those students who are seeking help and approach them themselves.

10.4 Survey of the Mathematics Learning Support Centre

During the academic year 2004/2005 a census was taken of the MLSC, which involved both academic and academic-related staff. Students who were recognised as frequent users of the MLSC were also asked to complete a similar questionnaire. With the possibility of extension and relocation of the MLSC, the purpose of these forms was to
obtain ideas, to receive staff perceptions of the students who use the MLSC, to receive student perceptions of the staff who work in the MLSC and to investigate awareness amongst staff and students of the services provided by the MLSC. There was a large overlap of questions in the staff and student forms to enable comparison of staff and student responses. From this it was hoped to evaluate the effectiveness of the MLSC, to determine whether the current support is suitable for dyslexic students and to determine if the MLSC is necessary. This is the first time, since the inception of the MLSC in 1995, that the views of academic staff, academic-related staff and students have been sought in such a formal and extensive manner on all issues concerning the Centre.

10.4.1 Background to the Survey

The census forms for the academic and academic-related staff were distributed during December 2004; at this time the MEC had submitted a bid to the HEFCE to obtain funding for a Centre for Excellence. The census forms were personally handed to 33 academic and academic-related staff in the School of Mathematics, which was, in effect, all staff in the Department who lecture or teach mathematics to undergraduates. The census form, which is contained in Appendix F, consists of 16 pages, split into 6 sections containing some direct questions with a variety of answers from which to choose, some question that require all applicable options to be selected and some requests for ideas and opinions. The six sections are:

1. Personal Details
2. General Questions
3. Reasons for Having a Mathematics Learning Support Centre
4. Future Expansion and Development of the Mathematics Learning Support Centre
5. Suggestions
6. Working in the Mathematics Learning Support Centre

The final section of the census form was to be completed only by those staff who had worked in the MLSC on a regular timetabled basis. Whilst consultants would be employed to assist with the design of a new Centre, if the bid were to be successful, it was felt that there should also be consideration given, where possible, to staff requirements and ideas. Twenty-nine staff completed the census form, which
represented a response rate of 87.8%. The names of these staff were entered into a prize draw, which was held on 17th December 2004. Of the 29 responses received, 23 members of staff had worked in the MLSC on a regular timetabled basis and six had not done so.

The HEFCE bid for a Centre for Excellence was successful and announced in January 2005. During the second semester of the same academic year the student questionnaires were made available to students using the MLSC. This form, which is also contained in Appendix F, consists of 14 pages, split into six sections with the same headings (apart from section 6 which is entitled ‘Support in the Mathematics Learning Support Centre’) as those distributed to academic and academic-related staff. It contains many identical questions, some new questions and some question asked from the opposite perspective. An example of a question posed from the opposite perspective is Question 6.8, which is not reported herein. Members of staff were asked “Do you feel that students prefer to see the same lecturer at each visit” and the students were asked, “Do you, where possible, time your visits to the MLSC to enable you to see the same lecturer(s)?” It was considered essential that the views of the students who use the MLSC should also, where possible, be considered regarding the design of the new Centre. Additionally, the questions that were presented to both sets of participants provided opportunity to analyse the responses from the staff and the student perspective on a large number of factors.

Personnel in the MLSC asked those students whom they recognised as attending the MLSC frequently to complete a questionnaire. Students who were occasional users of the Centre were not asked to complete a form as it was considered that this might be daunting for them and additionally these students would not have sufficient knowledge of the Centre to answer many of the questions contained in the form. An example of this is question 6.21, which asked “Have you used any of the handouts in the MLSC?”

Thirty-seven completed census forms containing, in the main, a large amount of descriptive and additional information, were received from students using the MLSC, the names of whom were entered into a prize draw which was held on June 3rd 2005. The responses included one completed census form from a student who had not undertaken his undergraduate studies at Loughborough University but had used the
Centre as a postgraduate student. There were, therefore, some questions that were not relevant to him and which he did not answer.

The questionnaires were given to all students who were known to be frequent users, or had been frequent users in previous year(s). To put this response in perspective, an attempt has been made to estimate the response rate of the frequently attending students. The statistics are, however, complicated by the fact that some students recognised as frequent attendees were in their second or later years of study and only attended the MLSC infrequently during the year of this study. To determine the response rate, it has, therefore, been decided to exclude six students who were in their second or later years of study who attended < 2 times during the academic year 2004/2005. The foundation, first, second and higher year students who are included in this estimate have all attended seven or more times. In total, 4866 individual visits were made to the MLSC during the academic year 2004/2005. During the second semester of this academic year there were 2346 individual visits, 328 of which were made by students who completed the questionnaire. The total number of students who attended the MLSC on seven or more occasions during the second semester was 84. Taking the 31 students who completed a questionnaire and attended on seven or more occasions gives an estimated response rate of 36.9%.

10.4.2 Preliminary Analysis of the Data

The academic and academic-related staff census forms had requested the participants to register their age in one of three categories; under 35 years of age, 35-45 years of age and 46 years of age and older. The student questionnaires had requested the students to record the age at which they had commenced their undergraduate studies.

The data was initially entered into a spreadsheet, with the academic and academic-related staff results being first grouped into whether or not they worked in the MLSC on a regular basis, and then subdivided into the three age ranges cited above. The student responses were grouped according to the age at which they commenced their undergraduate studies; 18 years of age, 19-21 years of age and 22 years of age or older.
Initially all comments and suggestions were recorded exactly as they had been presented on the census forms.

The responses to all questions were then scrutinised to determine if there were any questions where the age of the participants was instrumental in producing a differing response. Where this has been evident, the information is shown in the age categories that have been defined. On the academic and academic-related staff census forms, this was evident in the response to question 2.6. This question asked: "Are you aware that the MLSC runs a series of lunchtime support sessions?". On the student forms this was most pronounced on question 2.1. This question asked: "Did your university course start at a higher level than your mathematical background had prepared you for?"

There was only one question, which was posed to both staff and students that produced an answer that was gender-dependent. This was question 4.6, not reported herein, which asked, "Do you think that the MLSC should have its own toilets". In its present location the MLSC has male toilets close by, whereas it is a long way to the nearest female toilets.

From the results of those questions that were included in both the staff and student forms, it will be seen that the answers given by the students to some of the questions are almost diametrically opposite to those of the staff. For example, evidence of this will be seen in the responses given to question 3.2, which asked, "Why are students seeking help with mathematics".

Section 10.5 contains the results from the questions related to the research being undertaken in this thesis. The findings from the questions that were related to the environment, layout and design of the MLSC have informed the development of the new Centre and refurbishment of the original Centre. Findings from the questions relating to particular areas of mathematical difficulty, ability and anxiety will be published elsewhere. The questions reported in this thesis have been renumbered to give numerical progression throughout the section. The original question numbers are included in brackets to facilitate cross-referencing between the reported questions and the questions contained in the census forms and questionnaires, which are included in Appendix F.
10.4.3 Analysis

Both the staff and the student forms contained questions that were required to be answered in three different ways. One was the selection of an answer from a number of given options; another was the selection of all applicable answers from a number of given options and the third asked for opinions, suggestions and reasons to be given.

Regarding the questions that asked for the selection of one answer from a number of options, there were many forms received where both staff and students had chosen more than one option and also appended additional comments. With the questions that required the selection of all applicable answers from the given range of options, again additional comments were frequently appended. It was considered important to preserve this additional information; hence it was not, therefore, considered viable to use a statistical package to analyse the data, as this would have resulted in the loss of a large amount of the rich and descriptive information that had been provided.

In the analysis of those questions that had required a written response, comments of a similar nature were grouped together. For example in Section 5 (not reported herein), which required suggestions to be made appertaining to what constitutes a good working environment, comments such as, lots of natural light, room with windows, big windows and room with daylight were grouped together in a section entitled lighting.

For the questions where it was requested that all applicable options be selected and also questions where recipients had selected more than one option, the results are presented in a bar chart. The bar charts show the number of times an option was selected, represented as the % of each population choosing that particular option. In questions where only one option has been selected, the information is presented in a table, showing the percentage of each population selecting it.

10.5 Results of the Selected Questions

This section consists of three parts, each of which reports the findings from the questions that were presented in the census forms and questionnaires that relate to each
of the three questions that were posed in the research design.

10.5.1 Questions to Determine the Effectiveness of the MLSC

To determine an answer to the first question in the research design (How effective is the MLSC?), three hypotheses were posed. Namely, students use the MLSC all semester not just for help with coursework and past examination papers, staff and students are aware of the range of support that is provided by the MLSC and the MLSC helps students to understand the mathematical content of their programme of study.

The findings from the questions that were posed to the staff and/or the students to investigate these hypotheses now follow. Due to rounding, the response percentages do not always total 100%.

**Question 1** What do you consider is the most frequent reason for students using the MLSC? (staff – question 6.4).

What is your most frequent reason for using the MLSC? (students – question 6.4).

The results are shown in Figure 19.

![Figure 19: Most Frequent Reasons for Using the MLSC](image-url)
Although asked to tick the **most** frequent reason, some students and members of staff ticked more than one option. Only two members of staff selected the option 'other', with the comments that, “The Centre is used for problem sheets [weekly tutorial sheets that are handed out in lectures to provide practice on the topics that have been covered]” and “Students using the Centre want to learn, want to understand, want to do well and succeed”. However, 23 students selected this option, all mentioning tutorial sheets as being the reason for attending.

The answers that were given by the students to this question were dependent upon their age at the commencement of their course and are shown in Figure 20.

As can be seen, none of the mature students selected approaching examinations or coursework deadlines as the most frequent reason for attending the Centre. Two of these students added that they had a genuine desire to understand all the lecture material.

**Question 2**  What proportion of the time that students spend in the MLSC do you consider is due to approaching examinations or coursework deadlines? (staff – question 6.5).
What proportion of your time spent in the MLSC is due to approaching examinations or coursework deadlines? (students – question 6.5).

The results are shown in Table 44.

<table>
<thead>
<tr>
<th>Options</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 23</td>
<td>n = 37</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0)</td>
<td>3 (8.1)</td>
</tr>
<tr>
<td>Almost all</td>
<td>1 (4.3)</td>
<td>4 (10.8)</td>
</tr>
<tr>
<td>More than half</td>
<td>15 (65.2)</td>
<td>7 (18.9)</td>
</tr>
<tr>
<td>About half</td>
<td>8 (26.1)</td>
<td>12 (32.4)</td>
</tr>
<tr>
<td>Less than half</td>
<td>1 (4.3)</td>
<td>7 (18.9)</td>
</tr>
<tr>
<td>Almost none</td>
<td>0 (0.0)</td>
<td>4 (10.8)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 44: Proportion of Time Spent in the MLSC for Coursework and Examinations

It is apparent that staff and students have a significant difference of opinion regarding this issue. What is also apparent is that more than half the staff believed that the students’ most frequent reasons for using the MLSC were approaching coursework deadlines and examinations. The students’ responses to this question produced, what appears to be, a slight contradiction (when compared to question 1) as 26 of them stated that they spent half or more of their time in the MLSC due to approaching examinations or coursework deadlines. In question 1, 23 students cited the most frequent reason for using the MLSC as the completion of tutorial sheets. However, direct comparison is not reliable due to the wording of the questions. Question 1 asked for most frequent reason and question 2 referred to time spent in the Centre. It is quite feasible that students attended more frequently to complete tutorial sheets but their visits relating to coursework and examinations were of a lengthier duration.

Question 3 Are you able to determine if any of the students in the MLSC are regular attendees? (staff – question 6.6).

Do you visit the MLSC on a regular basis, i.e., at least once per week? (students – question 6.6).

The results are shown in Table 45.
Most staff could recognise some students who attended regularly, however, the staff were not asked how many regularly attending students they recognised.

**Question 4** If you have answered yes to the previous question, have these students made significant progress? (staff – question 6.7).  
Do you believe that attending the MLSC has improved your progress? (students – question 6.7).  

The results are shown in Table 46.

<table>
<thead>
<tr>
<th>Options</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 21</td>
<td>n = 37</td>
</tr>
<tr>
<td>Yes</td>
<td>4 (19.0)</td>
<td>34 (91.9)</td>
</tr>
<tr>
<td>No</td>
<td>1 (4.8)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Don't know</td>
<td>16 (76.2)</td>
<td>3 (8.1)</td>
</tr>
</tbody>
</table>

Table 46: Progress of Students who Frequently Attend the MLSC

Interestingly, whilst almost all the staff who work in the MLSC were able to recognise some regular attendees, they could not determine whether these students were making significant progress or not. However, when the limited amount of time that each individual member of staff spends in the Centre is combined with the range of questions from numerous modules that they encounter, the majority answer of ‘don’t know’ is not surprising. It is pleasing that the vast majority of the students did feel that they were making progress and also that these students are being pro-active in seeking help with the mathematical elements of their courses that are proving to be problematic.
Question 5  Are you aware that the MLSC runs a series of lunchtime support sessions? (staff and students – question 2.6).

The results are shown in Table 47.

<table>
<thead>
<tr>
<th>Options</th>
<th>Staff (n=6)</th>
<th>MLSC Staff (n=23)</th>
<th>Students (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>5 (83.3)</td>
<td>18 (78.3)</td>
<td>24 (68.6)</td>
</tr>
<tr>
<td>No</td>
<td>1 (16.7)</td>
<td>5 (21.7)</td>
<td>11 (31.4)</td>
</tr>
</tbody>
</table>

Table 47: Awareness of the Lunchtime Support Sessions

The answers that were given by the staff to this question were also dependent upon their age and are shown in Table 48.

<table>
<thead>
<tr>
<th>Options</th>
<th>All Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Staff less than 35 years old (n=4)</td>
</tr>
<tr>
<td>Yes</td>
<td>6 (100.0)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 48: Awareness of the Lunchtime Support Sessions (staff by age)

It is somewhat worrying that over 5/23 of the staff who work in the MLSC were not aware of these lunchtime sessions and would not have been in a position to suggest that a student attend them. The data also shows that older members of staff were less aware of the lunchtime sessions than the younger staff.

Question 6  Have you ever used the MLSC to obtain information sheets to distribute to students in your lectures or tutee groups? (staff only – question 2.8).

The results are shown in Table 49.

It is interesting to note that a greater percentage of non-MLSC staff than MLSC Staff are availing themselves of this facility.
Question 7 Have you ever consulted staff in the MEC regarding the GCSE or A-level syllabi? (staff only – question 2.9).

The results are shown in Table 50.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non-MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 23</td>
</tr>
<tr>
<td>Yes</td>
<td>1 (20.0)</td>
<td>3 (13.0)</td>
</tr>
<tr>
<td>No</td>
<td>5 (80.0)</td>
<td>20 (87.0)</td>
</tr>
</tbody>
</table>

Table 50: Staff Use of Expertise in the MLSC

One non-MLSC member of staff who had answered no to this question added the comment, “No, but only because I am very familiar with them both”. What is not clear is whether staff are familiar with school mathematics syllabi or unaware that many staff in the MLSC have expertise in this area.

Question 8 Are you aware that the MLSC has a specialist tutor to support students with dyslexia? (staff only – question 2.10).

The results are shown in Table 51.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non-MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 23</td>
</tr>
<tr>
<td>Yes</td>
<td>6 (100.0)</td>
<td>23 (100.0)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 51: Staff Awareness of Specialist Help in the MLSC
That all staff are aware of this provision is gratifying. The member of staff who is responsible for giving mathematics support to dyslexic students has also been active in researching areas relating to dyslexia and mathematics in HE. Through her work and research she has raised awareness of this SpLD throughout the School of Mathematics.

**Question 9** Are you aware that the MLSC runs a pre-university course for engineering students with weak or non-traditional mathematical backgrounds? (staff only – question 2.12).

The results are shown in Table 52.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non-MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 23</td>
</tr>
<tr>
<td>Yes</td>
<td>4 (66.7)</td>
<td>17 (73.9)</td>
</tr>
<tr>
<td>No</td>
<td>2 (33.3)</td>
<td>6 (26.1)</td>
</tr>
</tbody>
</table>

Table 52: Staff Awareness of Events Organised by the MLSC

It is worrying that 6/23 of the staff who work in the MLSC, on a regular timetabled basis, are unaware of this annual event.

**Question 10** Have you used any of the handouts in the MLSC? (students only – question 6.21).

The results are shown in Table 53.

<table>
<thead>
<tr>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 37</td>
</tr>
<tr>
<td>Yes</td>
<td>26 (70.3)</td>
</tr>
<tr>
<td>No</td>
<td>11 (29.7)</td>
</tr>
</tbody>
</table>

Table 53: Student Usage of Handouts in the MLSC

The handouts were designed primarily for those reading for a degree in the Faculty of Engineering or the Business School. Of the students completing the questionnaire,
48.6% were from the School of Mathematics and 51.4% were from Engineering, Physics and Science Foundation Studies. As over 70% of students are using the handouts, it appears that they are being used by a wider range of students than was originally intended. This in turn suggests that the changes that have been made to GCE A Level Mathematics have resulted in these handouts being of benefit to a wider range of students than was initially envisaged.

**Question 11** How would you describe the information and examples, which they contain? (students – question 6.22).

The results are shown in Table 54.

<table>
<thead>
<tr>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 26</td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>8 (30.8)</td>
</tr>
<tr>
<td>Good</td>
<td>13 (50.0)</td>
</tr>
<tr>
<td>Adequate</td>
<td>4 (15.4)</td>
</tr>
<tr>
<td>Insufficient</td>
<td>1 (3.8)</td>
</tr>
</tbody>
</table>

Table 54: Students’ Views on the Handouts in the MLSC

One student who had selected good also added, “Good, but could do with more complex material”.

The student who selected insufficient commented, “They are not detailed enough”.

This suggests that students need clearly written and detailed support material for mathematical topics of a higher and/ or more detailed level than that which is currently available.

**Question 12** Have you encountered any topics for which there was not a handout but you feel that one might have been useful? (students – question 6.23).

The results are shown in Table 55.
There was no relationship between the students who answered ‘yes’ to this question and their year of study.

The topics that were cited as not having a handout but for which one would be welcome are:

- Specific maths modules as the handouts are aimed more at engineering
- Basic statistics
- Most 1st year maths degree topics
- Methods of proving theories
- Fourier analysis
- Number theory
- Laplace Transforms
- Linear Algebra
- Computer packages

Students reading for a degree in mathematics and students in their second year of an engineering degree were responsible for the above remarks. This suggests that mathematics students require specific handouts and additionally many students, regardless of their course of study, also require help and support during their second year of mathematics modules.

**Question 13** Do you feel equipped to deal with the range of questions that you are asked in the MLSC? (staff – question 6.2).
Do you feel that the MLSC is able to assist with your mathematical needs? (students – question 6.2).

The results are shown in Table 56.
The comments made by staff who answered 'no' included:

Many specialist mathematics students attend the MLSC rather than tutorials.

The above comment may be interpreted in three ways:

i) The member of staff recognised mathematics students in the Centre who were registered on his or her module and was aware that they had not been attending tutorials.
ii) Whilst working with a student it became apparent that the student had not been attending tutorials.
iii) A student mentioned that, for whatever reason, they had not attended their timetabled tutorials.

The comments made by students who did answer 'no' included:

It depends on whether the lecturer is familiar with the module and how well the lecturer can explain a topic.

Nevertheless, it appears that not only are most students who attend the Centre helped with their mathematics but also that most staff are able to assist the students who are attending.

**Question 14** What proportion of the staff that you have encountered in the MLSC are friendly and helpful? (students only question 6.20).

Results are shown in Table 57.
Most of the students found all or almost all of the staff working in the MLSC to be helpful and friendly. However, it is of great concern that there are some members of staff who are not considered, by the students, to be friendly and helpful. A question that was asked to staff, but not reported in detail herein, was, ‘Why do you want to be involved with the MLSC?’ Of the 23 staff who work in the Centre three responded that it filled their teaching timetable, two responded that they did not wish to work in the Centre and one that their reason for doing so was that it might become a Centre for Excellence. It is imperative that members of staff who are working in the Centre are doing so because they genuinely want to help students understand the mathematical material that they are encountering.

### 10.5.1.1 Summary of the Effectiveness of the MLSC

The first hypothesis was that students use the MLSC all semester not just for help with coursework and past examination papers. There was a difference in opinion between staff and students regarding the most frequent reason for students availing themselves of the support in the MLSC. The majority of staff believed that students were attending due to coursework deadlines, whereas the option that was selected the most by students was that of ‘other’. However, the subsequent question asked for the proportion of time that was spent in the MLSC due to coursework deadlines and approaching examinations. The answers given by the students to this question, when compared to the previous question, suggested a contradiction; 26 students reported that they spent half or more of their time in the MLSC for these reasons. Whilst this appears, on first inspection, to be somewhat inconclusive, there are other factors such as observations undertaken by the author of this thesis and the usage statistics of the MLSC. There is

<table>
<thead>
<tr>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>19 (51.3)</td>
</tr>
<tr>
<td>Almost all</td>
<td>15 (40.5)</td>
</tr>
<tr>
<td>More than half</td>
<td>2 (5.4)</td>
</tr>
<tr>
<td>About half</td>
<td>1 (2.7)</td>
</tr>
<tr>
<td>Less than half</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Almost none</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 57: Proportion of Staff in the MLSC Considered by the Students to be Helpful
indeed an increase in usage of the MLSC at the end of each semester, which is just prior to the examination periods. The author of this thesis has also observed this increase in usage. However, it has also been observed that whilst many students attend the MLSC for help with their coursework and examinations, there are also a large number of students who are seeking help with questions on tutorial sheets. Furthermore, almost 70% of the students who participated in this research stated that they were attending the MLSC on one or more occasions per week – this suggests that these students are not attending the MLSC solely for help with coursework or past examination papers.

Considering those students who are attending the Centre on one or more occasions per week, it is feasible that whilst half their visits to the Centre are due to coursework deadlines or approaching examinations, the remaining time is spent on tutorial sheets. It is evident that whilst some students only attend the MLSC for help with coursework or approaching examinations, there are many frequently attending students who not only wish to succeed but also want to understand the material that they are encountering. It may be argued that these students are on the road to becoming autonomous learners at least in respect to their mathematics modules. Therefore, this first hypothesis is accepted although it is acknowledged that some students are using the Centre as a 'quick fix', i.e., as a means to obtaining marks in assessed material.

The second hypothesis was that staff and students are aware of the range of support that is provided by the MLSC. The majority of staff and students are aware of the lunchtime sessions that are provided by staff in the MLSC. Furthermore, all staff in the School of Mathematics are cognisant of the fact that the MLSC employs a specialist tutor to support dyslexic students with their mathematics. Regarding the handouts that are available in the Centre, the majority of students had used these and also found them to be of value although, from the comments received, there is clearly some demand for additional material. Only a small percentage of staff have obtained these handouts to distribute to their students, however, from the question that was posed it is not clear whether staff are unaware of this facility or prefer to explain topics to students in their own way. Furthermore, only a small percentage of staff have consulted with those based in the MEC regarding the current content of GCSE and GCE A Level Mathematics syllabi. What is not clear from this response is whether members of staff are fully conversant with current syllabi or unaware of the numerous changes to syllabi that have
taken place. The answers given indicate that the majority of staff and students are aware of the range of support that is provided by the MLSC.

The third hypothesis was that the MLSC helps students to understand the mathematical content of their programme. The majority of staff were of the opinion that they were able to help the students who attended the MLSC, and the majority of students who attended the Centre were also of the opinion that the staff they encountered were able to assist them with their difficulties. Staff in the MLSC were unsure if the students they were helping were making significant progress, but it must be borne in mind that this is difficult for staff to judge; they may be working in the Centre for only one hour per week and when the Centre is busy they will be spending only a short amount of time with each student. However, over 90% of participating students believed that they were making significant progress. There is sufficient evidence to accept this hypothesis.

These three hypotheses were posed to determine an answer to the question ‘How effective is the MLSC?’ All three hypotheses have been accepted and it is concluded that the MLSC is effective in helping students with the mathematical elements of their courses although there are some areas that need consideration. These areas will be discussed in the conclusion to this chapter (see section 10.6).

10.5.2 Questions to Determine the Effectiveness of the MLSC for Dyslexic Students

To determine an answer to the second question in the research design (How effective is the drop-in support for students with dyslexia?), two hypotheses were posed. Namely, staff in the MLSC have an understanding of the difficulties associated with dyslexia and are able to recognise students who might be dyslexic, and secondly, the MLSC provides suitable drop-in support for dyslexic students.

The findings from the questions that were posed to the staff and/ or the students to investigate these hypotheses now follow.
Question 15 Have you received any formal training or attended any Professional Development Course to enable you to recognise the symptoms of dyslexia? (staff only – question 1.4).

The results are shown in Table 58.

<table>
<thead>
<tr>
<th>Options</th>
<th>Less than 35 years old (%)</th>
<th>35 – 45 years old (%)</th>
<th>Over 45 years old (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 4</td>
<td>n = 9</td>
<td>n = 16</td>
</tr>
<tr>
<td>Yes</td>
<td>0 (0.0)</td>
<td>2 (22.2)</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>No</td>
<td>4 (100.0)</td>
<td>7 (77.8)</td>
<td>15 (93.8)</td>
</tr>
</tbody>
</table>

Table 58: Percentage of Staff who have Received Dyslexia Related Training

Although there was some difference in the responses received, according to the age of the respondents, the vast majority of staff in the School of Mathematics have not received any form of instruction that will enlighten them about the SpLD dyslexia or the ways in which dyslexia might manifest itself.

Question 16a Have you suspected that any of the students you meet in tutorials, personal tutee groups or during project supervision might be dyslexic, and if so how many? (staff only – question 2.11a).

The results are shown in Table 59.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non-MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 22</td>
</tr>
<tr>
<td>Yes</td>
<td>1 (20.0)</td>
<td>8 (36.4)</td>
</tr>
<tr>
<td>No</td>
<td>5 (80.0)</td>
<td>14 (63.6)</td>
</tr>
</tbody>
</table>

Table 59: Percentage of Staff who Recognised Students who might be Dyslexic

Three non-MLSC Staff added that they were aware that some of the students they saw were dyslexic as they had been informed of this either by the General Office or by the students themselves. The number of students that each member of staff suspected might be dyslexic ranged from one to three. Some members of staff, without any dyslexia
related training were, nevertheless, aware of this SpLD and recognised that some students they encountered might be dyslexic.

**Question 16b** Have you suspected that any of the students you meet in the MLSC might be dyslexic, and if so how many? (staff only – question 2.11b).

The results are shown in Table 60.

<table>
<thead>
<tr>
<th>Options</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 23</td>
</tr>
<tr>
<td>Yes</td>
<td>5 (21.7)</td>
</tr>
<tr>
<td>No</td>
<td>18 (78.3)</td>
</tr>
</tbody>
</table>

Table 60: Percentage of Staff who Suspected Dyslexia Amongst Students they encountered in the MLSC

Of those members of staff who suspected dyslexia amongst the students they encountered in the MLSC the number of students whom they considered might be dyslexic ranged from one to four. Again, there were some members of staff, who had not undergone any training to enable them to recognise dyslexia, who suspected that some students they met might be dyslexic. This suggests that information regarding dyslexia and its symptoms is now widespread and knowledge of this SpLD is growing.

If you have answered yes to 16a or 16b, why did you suspect that these students might be dyslexic?

In addition to comments that final year projects were unreadable, students were unable to spell, students were unable to read problem sheets and work was poorly structured there were also some lengthier explanations given:

In a couple of cases (which I only saw once) the students were profoundly confused. In another case I saw the student many times but he rarely, if ever, showed me his written notes and could not follow simple verbal arguments. He didn’t seem to understand what it means to understand something.
Poor grammar and difficulty understanding written material, even though the student had no difficulty discussing the subject face to face.

If you have answered yes to 16a or 16b, what action did you take?

In the cases where dyslexia was suspected as a result of reading the students' final year projects, no action was taken. Likewise for the students who were only encountered once in the MLSC, no action was taken. For the remaining cases, three lecturers suggested to the students that they contact the dyslexia-dedicated member of staff in the MLSC, two lecturers suggested to the students that they seek help from the university support services and one lecturer discussed the difficulties experienced by the student with the Director of the MEC. One lecturer also added the comment that he now reads questions aloud more frequently.

**Question 17**  If you are dyslexic or awaiting testing for dyslexia, does the available support in the MLSC meet your needs? (students only – question 6.24).

The results are shown in Table 61.

<table>
<thead>
<tr>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 4</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2 (50.0)</td>
</tr>
<tr>
<td>No</td>
<td>2 (50.0)</td>
</tr>
</tbody>
</table>

Table 61: Does the MLSC Meet the Needs of Dyslexic Students?

As expected, the number of dyslexic students completing the questionnaire was small and it is therefore difficult to draw any conclusions from the responses that were obtained. Referring back to earlier chapters, the three students who received one-to-one support (Chapter VI) all mentioned that the MLSC did not provide the level of support that they required. Furthermore, the explanatory case studies (Chapter VII, section 7.15 - hypothesis 7) determined that for half of the dyslexic students who participated in these studies, the MLSC drop-in support was inadequate for their needs.
Summary of the Effectiveness of the MLSC for Dyslexic Students

The first hypothesis in this section was that staff in the MLSC have an understanding of the difficulties associated with dyslexia and are able to recognise students who might be dyslexic. Very few of the staff had undergone any training to enable them to recognise the symptoms of dyslexia, yet some staff did suspect dyslexia amongst the students they came into contact with. However, their understanding of dyslexia is, in the main, limited to an association of the condition with poor spelling, reading and grammar. There does not appear to be widespread awareness, or understanding, of other difficulties that might be encountered due to a different thought processes or limitations in short term and working memory. Other than the comment made by one lecturer relating to the reading aloud of questions, there was not any evidence that staff have awareness of how their teaching style might be adapted.

The suitability of the MLSC for dyslexic students was also investigated in Chapters VI and VII. In Chapter VII, hypothesis 7 purported that drop-in support at the MLSC is inadequate for dyslexic students and this was accepted. It was believed that not many dyslexic students would complete the student questionnaire and this did prove to be the case. Considering the findings from the earlier chapters, and taking them in conjunction with the findings from the student questionnaires, it is concluded that the MLSC is not effective for dyslexic students. Furthermore, it is apparent that staff do not have a global understanding of the difficulties that might be associated with dyslexia.

The second hypothesis was that the MLSC provides suitable support for dyslexic students. On the basis of the questionnaires, the one-to-one support and the explanatory case studies this hypothesis is also rejected.

Questions to Determine the Necessity of the MLSC

To determine an answer to the final question in the research design (How necessary is the MLSC?), three hypotheses were posed, namely, the mathematical background of many students is inadequate for university level mathematics, there is a need for the MLSC on academic grounds and there is a need for the MLSC on economic grounds.
The findings from the questions that were posed to the staff and/or to the students to investigate these hypotheses now follow.

**Question 18** For what proportion of the students who you encounter do you consider that their undergraduate course started at a higher level than their mathematical background had prepared them for? (staff – question 2.1).
Did your university course start at a higher level than your mathematical background had prepared you for? (students – question 2.1).

The results are shown in Table 62.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non-MLSC Staff In tutorial groups (%)</th>
<th>MLSC Staff In tutorial groups (%)</th>
<th>MLSC Staff In the MLSC (%)</th>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For all</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>Yes</td>
<td>14 (37.8)</td>
</tr>
<tr>
<td>For almost all</td>
<td>1 (16.7)</td>
<td>1 (4.5)</td>
<td>4 (19.0)</td>
<td>No</td>
<td>23 (62.2)</td>
</tr>
<tr>
<td>For more than half</td>
<td>3 (50.0)</td>
<td>4 (18.2)</td>
<td>6 (28.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For about half</td>
<td>1 (16.7)</td>
<td>1 (4.5)</td>
<td>2 (9.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For less than half</td>
<td>1 (16.7)</td>
<td>15 (68.2)</td>
<td>9 (42.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For almost none</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 62: Undergraduate Courses Start at a Higher Level than Students’ Mathematical Backgrounds have prepared them for

The majority of staff in the three categories believed that for between less than half and more than half of the students their undergraduate courses had started at a higher level that their mathematical background had prepared them for. For the students encountered in tutorial groups, 50% of non-MLSC staff were of the opinion that this was true for more than half of the students they encountered, whereas 15/22 of MLSC staff were of the opinion that it was true for less than half of the students they encountered. Regarding students attending the MLSC, 9/21 of the staff working in the Centre were of the opinion that it was true for less than half of these students. The majority of the students’ responses indicated that they did not believe this to be the case; nevertheless 14/37 of the students did feel that their course had started at a higher level than their
mathematical background had prepared them for. These responses indicate that many students face a daunting experience with university level mathematics.

The answers that were given by the students to this question were dependent upon their age at the commencement of their course and are shown in Table 63.

<table>
<thead>
<tr>
<th>Options</th>
<th>18 years old (%)</th>
<th>19 – 21 years old (%)</th>
<th>Over 21 years old (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6 (25.0)</td>
<td>5 (45.5)</td>
<td>2 (66.7)</td>
</tr>
<tr>
<td>No</td>
<td>18 (77.3)</td>
<td>6 (54.5)</td>
<td>1 (33.30)</td>
</tr>
</tbody>
</table>

Table 63: Students by Age - undergraduate courses start at a higher level than their mathematical backgrounds have prepared them for

Regarding the staff perception of students in tutorial groups, there was one member of staff, who worked in the MLSC, but did not have a personal tutee group and therefore abstained from answering this question. Two staff members, who worked in the MLSC, did not answer the question relating to their observations of students in the Centre, one of whom supplied the comment, “I have not worked in the MLSC for sufficient time to express an opinion”.

One student who had stated that the undergraduate course had not started at a higher level than her background had prepared her for explained:

This was due to my having undertaken further mathematics [at A Level] and many of the topics I had spent considerable time on in further mathematics were brushed over quickly, without having taking this examination I would have been struggling.

**Question 19a** During the current academic year what proportion of the students, that you have encountered in tutorials and personal tutee groups, do you feel should have been admitted to a degree programme? (staff only – question 2.16a).

The results are shown in Table 64.
<table>
<thead>
<tr>
<th>Options</th>
<th>Non MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 20</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0)</td>
<td>3 (15.0)</td>
</tr>
<tr>
<td>Almost all</td>
<td>4 (66.7)</td>
<td>11 (55.0)</td>
</tr>
<tr>
<td>More than half</td>
<td>1 (16.7)</td>
<td>5 (25.0)</td>
</tr>
<tr>
<td>Less than half</td>
<td>1 (16.7)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Almost none</td>
<td>0.0</td>
<td>1 (5.0)</td>
</tr>
<tr>
<td>None</td>
<td>0.0</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 64: Staff Opinion of the Proportion of Students Encountered in Tutorials and Tutee Groups who should have been Admitted onto a Degree Programme

The majority of both non-MLSC and MLSC staff were of the opinion that almost all of the students they encounter in tutorials and personal tutee groups should have been admitted to a degree programme even though in the previous question the majority of non-MLSC staff had expressed the opinion that undergraduate courses started at a higher level than these students’ mathematical backgrounds had prepared them for.

**Question 19b** During the current academic year what proportion of the students, that you have encountered in the MLSC, do you feel should have been admitted to a degree programme? (MLSC staff only – question 2.16b).

The results are shown in Table 65.

<table>
<thead>
<tr>
<th>Options</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 17</td>
</tr>
<tr>
<td>All</td>
<td>2 (11.8)</td>
</tr>
<tr>
<td>Almost all</td>
<td>6 (35.3)</td>
</tr>
<tr>
<td>More than half</td>
<td>9 (52.9)</td>
</tr>
<tr>
<td>Less than half</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Almost none</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 65: Staff Opinion of the Proportion of Students Encountered in the MLSC who should have been admitted onto a Degree Programme

Of the students that are encountered in the MLSC, over 50% of the MLSC staff believe that more than half of these students should have been admitted onto a degree programme even though in question 18, 42.9% of these staff believed that for the
students attending the MLSC their undergraduates courses had started at higher level than their mathematical background had prepared them for.

**Question 20** Why are students seeking help with mathematics? (staff and students – question 3.2).

Staff and students were requested to tick **all** applicable options.

The results are shown in Figure 21.

![Figure 21: Reasons for Students Seeking Help with Mathematics](image)

Here it can be seen that whilst none of the staff felt that students were seeking help due to an increase in the academic level of courses, over 50% of the students believed that this was one of the reasons. Additionally, over 50% of MLSC and non-MLSC staff selected the option of lowered academic recruitment level, yet less than 10% of students attributed their reason for seeking help to this option.
The answers that were given by the students to this question were dependent upon their age at the commencement of their course and are shown in Figure 22.

![Bar chart showing percentages of students choosing different reasons for seeking help with mathematics by age.](chartimage)

**Figure 22: Reasons (by student age) for Students Seeking Help with Mathematics**

As can be seen, approximately 65% of students who commenced their studies at 18 years of age selected ‘increased academic level of study’, whereas none of the students who were over 21 years of age at the commencement of their studies selected this option.

The most frequent comments made by members of staff in the category ‘other’ were related to the availability of the facility, changes in the mathematical background of the students and the difficulty of mathematics. Examples of these comments are:

- Because it [the MLSC] is there and because it [mathematics] is hard.
Unrealistic expectations by some departments and staff. Inadequate knowledge by staff of the gap between demands of a course and the prerequisite knowledge and skills.

The most frequent comments made by students in the category ‘other’ were related to the amount of new material that was encountered, the different way of delivery of material from that encountered at school, speed of delivery, lack of commitment pre-university and laziness. Examples of these comments are:

Different challenging aspects as mainly new material is being covered and often further clarification is required.

Students have been used to small classes with a good personal relationship with their tutors, university is a new method of teaching that many students are unfamiliar with.

Courses move quickly and lecturers expect students to instantly understand.

Lack of commitment in mathematics before coming to university and too lazy to do self-study.

**Question 21** For students who were unable to understand your initial explanation, for what proportion of them was this lack of understanding due to their mathematical background being weaker than was immediately apparent? (staff question 6.9).

If there have been occasions when you were unable to understand the initial explanation given by a lecturer, how often was this due to the lecturer assuming that your underlying mathematical background is greater than it actually is? (students – question 6.9).

*The results are shown in Table 66.*
It is clear that a greater percentage of staff than students believe that it is a lack of understanding of topics that underpin the mathematics encountered in HE that is having a detrimental effect on comprehension.

<table>
<thead>
<tr>
<th>Options</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 21</td>
<td>n = 37</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0)</td>
<td>3 (8.1)</td>
</tr>
<tr>
<td>Almost all</td>
<td>5 (23.8)</td>
<td>7 (18.9)</td>
</tr>
<tr>
<td>More than half</td>
<td>6 (28.6)</td>
<td>5 (13.5)</td>
</tr>
<tr>
<td>About half</td>
<td>4 (19.0)</td>
<td>5 (13.5)</td>
</tr>
<tr>
<td>Less than half</td>
<td>4 (19.0)</td>
<td>8 (21.6)</td>
</tr>
<tr>
<td>Almost none</td>
<td>1 (4.8)</td>
<td>5 (13.5)</td>
</tr>
<tr>
<td>None</td>
<td>1 (4.8)</td>
<td>4 (10.8)</td>
</tr>
</tbody>
</table>

Table 66: Mathematical Background Related to Impact on Understanding

Question 22  What proportion of students were able to understand your initial explanation? (staff – question 6.10).

How often have you been able to understand the initial explanation given by a lecturer in the MLSC? (students – question 6.10).

The results are shown in Table 67.

<table>
<thead>
<tr>
<th>Options</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 22</td>
<td>n = 37</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0)</td>
<td>2 (5.4)</td>
</tr>
<tr>
<td>Almost all</td>
<td>8 (36.4)</td>
<td>19 (51.4)</td>
</tr>
<tr>
<td>More than half</td>
<td>7 (31.8)</td>
<td>9 (24.3)</td>
</tr>
<tr>
<td>About half</td>
<td>6 (27.3)</td>
<td>6 (16.2)</td>
</tr>
<tr>
<td>Less than half</td>
<td>1 (4.5)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Almost none</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0.0)</td>
<td>1 (0.0)</td>
</tr>
</tbody>
</table>

Table 67: Percentage of Students able to Understand Initial Explanation

The majority of staff were of the opinion that more than half of the students understood their initial explanation and this was endorsed by the students themselves.

One student who selected almost all of the time added the comment, “Almost all of the time with a good lecturer but less than half with a bad lecturer".
The responses indicate that most staff working in the MLSC are aware of the students' level of mathematical knowledge and understanding.

**Question 23** Is there, on academic grounds, a need for the MLSC? (staff and students question 3.3).

The results are shown in Table 68.

<table>
<thead>
<tr>
<th>Options</th>
<th>Staff Non MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 23</td>
<td>n = 37</td>
</tr>
<tr>
<td>Yes</td>
<td>5 (83.3)</td>
<td>23 (100.0)</td>
<td>35 (94.4)</td>
</tr>
<tr>
<td>No</td>
<td>1 (16.7)</td>
<td>0 (0.0)</td>
<td>2 (5.6)</td>
</tr>
</tbody>
</table>

Table 68: Is there, on academic grounds, a need for the MLSC?

Almost all the staff and students were in agreement that there is, on academic grounds, a need for the MLSC. The main points raised by staff were that it helps students from differing backgrounds, helps to maintain the university standards as students are arriving with less mathematical knowledge than was previously the case, helps to prevent failure, helps to 'sell' the university and staff in the Centre undertake educational research. The main points raised by students were that it helps to bridge any gaps between incoming mathematical knowledge and that which is required at university, it is a big jump from A Level to university mathematics, differing background of students and improves the mathematical standard of students.

More detailed comments from staff included:

Students are admitted who do not have some basic core skills. If they hope to succeed in their main courses where these skills are required then support is essential.

Needed to address the lowering level of incoming students mathematical knowledge and to try to maintain the university’s standard in mathematics.
One of its main aims is to research innovative teaching methods which is good in my view.

To improve the culture of learning mathematics amongst the student body.

There is a real problem in the UK and elsewhere. We need to expend more effort in getting students to expect to remedy shortcomings and to want to improve/succeed.

More detailed comments from students included:

To help bridge any gaps in previous mathematics knowledge and to prevent these small gaps becoming big holes.

Mathematics is the backbone of many degrees. It is also a vast and ever-changing subject. A central store of knowledge and support is needed.

It is a big jump from A Level mathematics to university mathematics, the MLSC helps many students to pass their examinations.

One reason for there not being academic grounds for the MLSC, given by both staff and students, was that students should be properly prepared and arrive at university with the necessary mathematical knowledge. Additionally, one student commented, “All the material is covered in lectures”.

**Question 24** Is there, on economic grounds, a need for the MLSC? (staff and students question 3.4).

The results are shown in Table 69.

<table>
<thead>
<tr>
<th>Options</th>
<th>Non MLSC Staff (%)</th>
<th>MLSC Staff (%)</th>
<th>Students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 3</td>
<td>n = 16</td>
<td>n = 27</td>
</tr>
<tr>
<td>Yes</td>
<td>3 (100.0)</td>
<td>16 (100.0)</td>
<td>27 (100.0)</td>
</tr>
<tr>
<td>No</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 69: Is there, on economic grounds, a need for the MLSC?
All staff and students who answered this question were in agreement that there is on economic grounds a need for the MLSC.

There were 10 staff and 10 students who did not answer this question. Several of the staff who did not provide an answer wrote that they were either unsure or did not understand the question. During the first two weeks of distributing the student forms a member of staff in the MLSC received several queries from students who did not understand this question. As subsequent student forms were handed out, it was explained to students that in this question 'economic reasons' referred to university loss of revenue and/or costs incurred by students who subsequently fail their year or drop-out of their course.

Comments made by staff included:

Politically a good idea and likely to attract a lot of funding.

In a litigative society, Loughborough University being seen to provide such support can only help in cases in which failed students sue the university.

Keeps the Department of Mathematical Sciences in favour re: service teaching. Helps recruitment significantly. Helps retention and progression. Improves student satisfaction and this will be increasingly important. Many universities have closed their mathematics departments. The MLSC is a very visible commitment to student support and so will help secure a future for mathematics at Loughborough. It generates significant external income, which helps many students indirectly e.g., through free access to resources.

Increased failure rates would have economic effects, especially via effect on reputation and league table rankings of Loughborough.

Comments made by students included:

Improved grades; without the MLSC grades would go down and also position in league tables. This would then result in less funding.
To avoid high dropout rates and because university is very expensive, students cannot afford to re-sit a year or start again.

It is economically efficient if in-depth mathematical work takes place outside lectures. By having lecturers timetabled to be available during the day, it prevents them being constantly interrupted and allows them to continue their own research.

10.5.3.1 Summary of the Necessity of the MLSC

The first hypothesis in this section was that the mathematical background of many students in inadequate for university level mathematics. This hypothesis is upheld, none of the MLSC or non-MLSC staff whether referring to students encountered in tutorials or the MLSC selected almost none or none. Regarding the students, whilst over 60% did not believe that this was the case there were almost 40% who were of the opinion that this was true. It is evident that there are differences of opinion but what cannot be ignored is that this hypothesis is justifiable for many students.

An impasse was in evidence between staff and students regarding the reason why students were seeking help with mathematics. Over 80% of non-MLSC staff and over 90% of MLSC staff were of the opinion that the reason was due to a decrease in the knowledge of incoming students. However, over 50% of students believed that this was due to an increased academic level of courses. Their opinion is not surprising; students entering university with the pre-requisite A Level grades are, as a result of their qualifications, likely to attribute any shortcomings in their comprehension to an increase in academic requirements. On the other hand, for the mature students, who it may be considered are more aware of the changes that have taken place in GCE A Level mathematics syllabi, almost 70% were in agreement with the staff response.

The second hypothesis, that there is a need on academic grounds for the MLSC, is upheld. There was strong agreement between both staff and students that this is indeed the case.
Finally, the third hypothesis, that there is a need for the MLSC on economic grounds, is also accepted as, amongst staff and students who answered this question, there was unanimous agreement that this was indeed the case.

Therefore, it can be concluded that the MLSC is necessary.

10.6 Conclusion and Recommendations

It has been determined that:
- There is a need for the MLSC
- The MLSC does not provide adequate support for dyslexic students
- The MLSC is necessary.

Despite the conclusion that there is a need for the MLSC it is worrying that some students may only be seeking help with assessed work. Regarding staff in the Centre, effort must be expended to ensure that they are working in the Centre because they genuinely want to help students to understand their mathematics. It is also of concern that some staff working in the MLSC are not cognisant of the range of difficulties that may be faced by dyslexic students.

It is recommended that staff need to be alert to students in the Centre who may require assistance. Staff should not use their time in the Centre to pursue their own work when it is detrimental to students who are seeking help. Staff must also be instructed that they must not make disparaging remarks such as, 'This is elementary' (see section 10.2.3).

Staff in the MLSC are mathematicians and need to be made aware of the academic level of students who are seeking help in the MLSC. Many students who are seeking help are reading for engineering degrees and may not have an A Level background. Moreover, for these students with a non A Level background, their GCSE qualification may have been obtained several years previously. It is recommended that all staff who work in the MLSC should undertake a professional development course detailing the content of GCSE and GCE A Level Mathematics.
It is also apparent that more stringent guidelines for staff need to be introduced regarding the assistance that may be given to students who are seeking help with coursework.

Publicity needs to be generated by the MLSC and directed at all students to inform them that mathematics is a linear topic that builds on earlier material. Therefore, it is a necessity that material is understood as it is encountered and a 'quick fix' at the end of a semester is not a viable option.

The MLSC must be responsible for disseminating the range of support and facilities that it offers. To raise awareness of academic activities that are administered by the MEC, it is suggested that literature detailing workshops, lectures and events should be distributed to all members of staff. In particular, it is considered important that all staff should be aware of the lunchtime support sessions. The census revealed that 16.7% of non-MLSC Staff and 21.7% of MLSC Staff are unaware of these sessions and therefore are not in a position to recommend them to those students who may be most in need of this support.

There is scope for additional Professional Development of the staff in the School of Mathematics. It is recommended that all staff, whether or not employed in the MLSC, should undertake a compulsory course detailing SpLDs and their manifestations. This, it is considered, is of vital importance if the School of Mathematics is to comply with the SENDA, a requirement of which is that universities should be pro-active in addressing the needs of students with disabilities. It is also felt that it might be prudent for the Department to organise a presentation of the most pertinent aspects of this legislation to all departmental staff.
XI
Conclusion

This final chapter begins by collating the research findings from each of the earlier chapters and discusses the implications associated with these findings. It then links these findings to the research questions that were initially posed and succinctly presents the answers to these questions. It continues with suggestions for improvements to the MLSC and makes specific recommendations for measures to be introduced in the School of Mathematics at Loughborough University. Other recommendations that are made have the potential for uptake by the parts of the HE sector in the UK, which offer courses with a mathematical component. The final section details areas that have been researched in this work but would benefit from larger scale research. This section also makes suggestions for additional research to be undertaken in areas where the findings would increase the knowledge base related to dyslexia in HE, which, ultimately, should prove beneficial to dyslexic students.

11.1 Summary of the Research Findings

In Chapter III it was identified, from HESA data, that there has been a steady increase in the number of dyslexic students entering HE in recent years. What was not apparent from these figures was the number of students who are diagnosed as dyslexic after commencing their undergraduate studies. This thesis has attempted to answer this question. Testimony by a member of the ELSU and members of Support Units at Hull and Cardiff Universities told of the significant growth in the number of students approaching them for dyslexia screening after their arrival at university. Many of these students had been told by staff at their former schools or colleges to undertake screening for dyslexia on arrival at university. At Loughborough University, there is widespread literature detailing dyslexia and leaflets with a checklist are prominently displayed throughout the campus. When completed, the answers indicate if there is a possibility of dyslexia. This publicity has also resulted in many students seeking advice and subsequently being diagnosed as dyslexic. Additionally, academic members of staff
were also referring students to the ELSU or the dyslexia-dedicated member of staff in
the MLSC. This could be a direct result of greater awareness amongst staff regarding
disabilities and through individual members of staff within departments being given
responsibility for Disability and Special Needs.

Analysis of the number of students being diagnosed as dyslexic after commencing their
undergraduate studies confirmed that there has been significant and ongoing growth in
this area since the academic year 2000/2001. There are two areas of concern connected
with those students who come forward for screening as a result of being recommended
to do so by their prior educational establishments. The first is that had these students
been diagnosed as dyslexic whilst at school or college, they could have received
additional support during their pre-university education, and support would also have
been available to them on entry to university. What also became evident was that many
students had to wait for a considerable time to see an EP, which obviously resulted in
the provision of support not being implemented until the outcome was known. It
appears that schools are reluctant to determine whether pupils are dyslexic or not; what
is not apparent is whether this is due to issues connected with 'labelling' or due to
financial considerations. It is these financial issues that form the second area of concern.

At Loughborough University, students believing themselves to be dyslexic are
interviewed by a member of staff from the MLSC, the ELSU or the DANS and, if they
wish to proceed, a member of the ELSU then administers a DAST to determine if the
student is considered to be at risk of being dyslexic. This process is time consuming
and has cost implications for the university. Additionally, home students considered to be at
risk are then, if they wish to proceed, referred to an EP who will determine whether the
student is dyslexic or not. The cost for this is also borne by Loughborough University. It
may well be the case that budgetary concerns within schools and colleges are resulting
in the cost of screening and testing for dyslexia being passed on to the HE sector.

There is also another group of students for whom the manifestations of dyslexia only
became apparent after commencing HE. For these students there are additional issues to
be considered. First there is the shock of discovering that despite obtaining
qualifications of sufficient merit to enable them to enter university, there is 'something
wrong with them'. This group has not grown-up with the knowledge that they are
dyslexic and have not received any support during their former education. In the
exploratory studies (Chapter V), Tom mentioned that he felt relieved to know that there was a reason for his difficulties, whereas Robert initially felt shy about being diagnosed as dyslexic. In the explanatory studies (Chapter VII), Edward initially felt confused and scared when it transpired that he was dyslexic but was also relieved to find that there was an explanation for his difficulties. This is in accord with Stuart who found slight relief in discovering that there was a reason for the difficulties he had encountered. Section 11.4 of this chapter suggests further research be undertaken with students who are diagnosed as being dyslexic after commencing their undergraduate studies.

In Chapter V, the exploratory multiple-case studies investigated whether there was any evidence to suggest that students who had been diagnosed as dyslexic after commencing their undergraduate studies were impeded in their learning and understanding of mathematics as a direct result of their dyslexia. It was determined that there is evidence to suggest that these students experience problems with mathematics that are directly related to their dyslexia. All of the participating students experienced difficulty with note taking and with reading and recall of material.

One-to-one support, provided to three students by the author of this thesis, was undertaken to enable any encountered difficulties to be witnessed and ways of resolving the difficulties to be investigated. During this support several areas of difficulty were witnessed. As detailed in Chapter VI, the majority of the difficulties were related to incorrect or incomplete lecture notes, multi-stage operations, visual disturbance being encountered when working with matrices, systems of equations and reading from statistical tables, text based material such as encountered in statistics, use of notation and recall of formulae. Additionally, all three students found the support in the MLSC to be inadequate for their needs. It was found that by: covering material at a pace that suited the individual student, breaking down multi-stage operations into smaller more manageable tasks, devising aids to memory such as through the provision of visual prompts or by creating rhymes, explaining the interrelations between topics, by using squared paper and by creating simple 3-d models, these students could be helped to overcome or to minimise many of their difficulties. It is also believed that seeing the same tutor on a regular basis helped these students. With the provision of a sympathetic environment, a comfortable working relationship evolved; the students were able express their anxieties and ask the same question on several occasions without fear of
derision. In short, these students were helped by the provision of appropriate one-to-one mathematical support. The fact that members of the ELSU, and members of dyslexia support units in other institutions, recognise that dyslexia has the potential to affect adversely the learning and understanding of mathematics in HE, and the fact that it has been shown that these students may be helped to mitigate their difficulties, raises the question of why this support is not available throughout the whole of the HE sector.

The explanatory multiple-case studies detailed in Chapter VII were undertaken with dyslexic engineering students and a control group of non-dyslexic engineering students. These were undertaken to investigate how dyslexic students are impeded in their learning and understanding of mathematics, whether there are particular areas of mathematics that pose significant difficulty, and how these students might be disadvantaged by current practices of delivery and assessment. When the dyslexic students were compared to the non-dyslexic students, significant differences were evident. In particular, it was obvious that many of the dyslexic students, unlike the majority of the non-dyslexic students, experienced difficulty with: note-taking, multi-stage mathematical operations, working with rows and columns of figures and systems of equations due to visual disturbance, descriptive text, the recall of notation and formulae, tutorial support, the drop-in support that is available in the MLSC and some forms of delivery and assessment. In addition, it was determined that all the dyslexic students frequently obtained incorrect answers to material that they understood, whereas this was the case for only one of the non-dyslexic students.

Comparison between the dyslexic and non-dyslexic control group also confirmed differences between the two groups in their approach to study and revision. For example, eight of the dyslexic students used mind maps to help themselves to understand and recall mathematical material. Furthermore, five of the dyslexic students referred to their need to have a 'global picture' of the material they were encountering. This was not referred to by any of the non-dyslexic students. None of the non-dyslexic students used mind maps for mathematics and many of them failed to comprehend how they could be used for this subject and treated the idea with disbelief. In contrast mind maps were cited as being an invaluable aid to learning and revision by many of the dyslexic students.
What these studies also showed was that seven of the dyslexic students who used mind maps preferred to draw them themselves even though they had been supplied with software designed for this purpose. This is in accord with the findings from the one-to-one case studies. It was also determined that the ‘read and write’ software had a mixed response amongst the dyslexic students. Daniel and Jack found this to be useful, Anthony used it occasionally, but Edward and James found it to be unsuitable for their course of study. This is an area of some concern from two viewpoints. Firstly from the students’ perspective, many of them are being provided with costly software that they either do not wish to have or find unsuitable for their course of study. It may be that the money could have been better spent on the provision of additional one-to-one support, which they find to be extremely helpful. Secondly, from a taxpayer’s perspective, it appears that their money is, in some cases, being used inappropriately, albeit with the best of intent. It is acknowledged, and worthy of mention, that it is extremely difficult for those staff who prepare needs assessments to be able, with any certainty, to determine exact individual student requirements. Furthermore, it might be argued that it is better to err on the side of caution rather than to run the risk of depriving a student of some form of support that might prove to be beneficial. One solution to this impasse might be to loan software, recording devices etc., to students for a trial period and then re-assess their personal requirements after a set period of time.

There were also mixed opinions regarding the use of coloured overlays when these had been recommended. For example, Edward, Stuart and Daniel used them, Jack and Lee did not do so and Bob preferred to uses tinted glasses. Neither of the students in the one-to-one case studies used the overlays that had been recommended. It is also of interest that amongst those dyslexic students who commented on the adequacy of the support that had been provided (this includes, for example, note takers, software, extra time, and one-to-one tuition), Edward, Phyllis, Alan and Bob were of the opinion that it had been adequate whereas Stuart and Lee did not find this to be the case. Stuart was also of the opinion that his prior exposure to mathematics had not placed him in a position to cope with the rigour of university level mathematics and there was insufficient time available for the amount of support he required with this subject. Lee found lecturers unable to comprehend that difficulties might be encountered with ‘lower level’ mathematics and that students might need help to overcome these difficulties.
Furthermore, there was also evidence of difference in learning styles amongst the dyslexic students, for example, Daniel found the HELM booklets to be excellent whereas Anthony described these as being confusing. Chris and James preferred to copy down exactly what was written on the blackboard, Alan and Daniel preferred the use of bullet points and Anthony, Joseph and Lee did not like the use of pre-prepared transparencies. There was also division regarding the use of handouts, for example; Anthony would have liked handouts to be provided after a lecture whereas there were six of the dyslexic students who would have liked these to be provided prior to the lecture.

There were other areas of concern that came to light during the interviews with the dyslexic students. For example, Stuart, Alan and Bob described themselves as having difficulties with their timetables, which had resulted in them either missing lectures or arriving at an incorrect time and Bob described himself as being forgetful. Regarding the employment of PhD students for tutorials there was also discord. Phyllis and Alan found PhD students to be unsatisfactory whilst Jack found them to be more in touch with students' level of understanding. This suggests that the differences between individual PhD students may have implications relating to selection and training. The extra time allowance in examinations also resulted in differences of opinion; Edward and James found this to be beneficial whereas Daniel had not used it. Jack found the extra time to be useful when examinations required a large amount of reading and writing to be undertaken.

Dissemination of the findings and measures that have been implemented has already commenced (for publications in press see page v of this thesis).

A further area of concern that arose from the one-to-one case studies and the explanatory case studies was that of CAA; it was this form of testing that proved instrumental to Patrick (Chapter VI, section 6.1.1) and Alan (Chapter VII, section 7.4.1) taking the first steps to determine whether or not they were dyslexic. To explore what might prove to be a discriminatory form of testing an exploratory study was undertaken and detailed in Chapter VIII. This study was designed not only to investigate whether dyslexic students are disadvantaged by CAA of mathematics, but also to determine the effects that different media combinations might have on both dyslexic and non-dyslexic
students, and whether this form of testing gives a realistic indication of mathematical ability. Due to the size of the study and the small number of dyslexic students who participated the findings proved to be inconclusive. Nevertheless, it was determined, through analysis of the students' paper-based scripts, that if the manual marking had been undertaken then 28 of the students would have received significantly higher marks. It was also determined that eight of the ten students who were assigned to the text and diagram version were of the opinion that this had aided their performance. There were also comments received from two students who were assigned to the text only version that diagrams would have aided their performance. Regarding the audio representation, eight of the students believed that this representation had aided their performance. One highly pertinent suggestion was received from a dyslexic student who pointed out that key words should be presented in bold font.

It is also of interest that two-thirds of the participating students did not believe that CAA gave a realistic indication of their mathematical ability.

Chapter IX investigated the extent, and range of provision, of mathematics support in HE institutions. It was established that there had been an increase in the number of institutions offering mathematics support since 2001. Out of the 106 universities contacted there were 101 responding institutions. Of these responding institutions, 66 (65.3%) offered some form of learning support. There were also some institutions who recognised the need for introducing mathematics support but were unable to proceed due to lack of funding.

Five universities who provided some form of mathematical support over and above that provided by timetabled tutorials and personal tutor groups were visited. What emerged from these visits was not only evidence of dedicated staff providing enthusiastic help, a range of excellent ideas and welcoming work areas, but also that two of the Centres had had dyslexic students referred to them by their Learning Support Services. This established that dyslexic students are encountering difficulties with mathematics at institutions other than Loughborough.

The survey of institutions that do provide some form of mathematics support found that one-to-one mathematics support for dyslexic students who are eligible for additional
tutorial support was only available in 25% of those who responded. This is an area of great concern; it has been shown that dyslexic students who are encountering difficulties with their mathematics can be helped to succeed. This has the implication that dyslexic students who are reading for degrees with a significant mathematical component at institutions where this form of support is not available are likely to be disadvantaged when compared to those students who are provided with support.

In Chapter X, observations in the MLSC determined that the difficulties being encountered by students, the majority of whom were believed to be non-dyslexic, were in general of a different nature to those witnessed during the provision of one-to-one support to the dyslexic students. It was also observed that many students using the Centre were lacking in rudimentary mathematical knowledge and were inadequately prepared for university level mathematics. The majority of staff working in the Centre were seen to be friendly, helpful and approachable, nevertheless, it is of concern that in a minority of cases this was not true. Some staff were, on occasions, so engrossed in their own work that they failed to notice students waiting for help, there were also instances of staff telling students that they should know the answers to the questions they had posed or that their queries were elementary. None of the aforementioned is considered as good practice by staff employed in the Centre. There were also differing responses from lecturers to questions that were asked about coursework; some lecturers worked through a similar question, others established whether a particular method, which would be needed in the coursework, was understood. However, there were occasions where the response was a bluntly delivered refusal of help.

From the staff census forms and the student questionnaires it was determined that the MLSC is effective. In general, students are not attending the MLSC solely for help with coursework or past examination papers, although it is acknowledged that some students use the Centre as a ‘last minute’ resource. It was also determined that the majority of staff and students are aware of the range of support that is provided by the MLSC. Finally, and importantly, there was agreement between staff and students that the help provided was helpful and beneficial.

Regarding dyslexic students, the findings from the one-to-one cases studies (Chapter VI), the explanatory studies (Chapter VII) and the MLSC census forms determined that
the MLSC does not provide adequate drop-in support for dyslexic students due to the limited time available with the lecturer on duty and the number of different lecturers that may be encountered. Some members of staff in the MLSC were aware of dyslexia and able to recognise various ways in which dyslexia might be manifested, however, their understanding of this SpLD was limited to an association with poor spelling, reading and grammar. There was not, with the exception of one instance, any evidence to suggest that staff have any perception of the difficulties that might be encountered or the ways that their teaching methods might be adapted to suit students with different learning requirements.

The third question posed was to determine whether or not the MLSC is necessary. The findings were all in accord – the MLSC is a necessity rather than a nicety. It was established that the mathematical background of many students is inadequate for university level mathematics and that there is a need on both academic and economic grounds for the MLSC.

11.2 The Research Questions Revisited

Four research questions were posed at the beginning of this thesis and each of these will now be revisited. The answers have been determined by the research undertaken and reported on in earlier chapters; this has also been summarised in section 11.1 of this chapter.

11.2.1 Research Question 1

This question asked ‘Does dyslexia impede the learning and understanding of mathematics in HE and, if so, in what areas are particular difficulties encountered and can these difficulties be mitigated?’

The exploratory case studies (Chapter V), the one-to-one case studies (Chapter VI) and the explanatory case studies (Chapter VII) determined that there is evidence to suggest
that dyslexic students are impeded in their learning and understanding of mathematics as a direct result of their dyslexia.

The main difficulties were with: note taking, multi-stage mathematical operations, visual disturbance, use of notation, reading and remembering material, and recall of formulae. In the one-to-one case studies it was shown that is possible to help dyslexic students to compensate for their difficulties and in some cases to overcome them. This was achieved by: much repetition of work, which enabled methods to be committed to long-term memory, the breaking down of lengthy multi-stage operations into smaller more manageable sized chunks, use of colour coding to help students to visualise sequences, and the use of rhymes and mnemonics to aid recall of material.

11.2.2 Research Question 2

This question asked ‘Are dyslexic students disadvantaged in their learning and understanding of mathematics by practices in HE and, if so, what are these practices’.

It was found that dyslexic students are disadvantaged by practices at Loughborough University. Eight of the 12 dyslexic students who participated in the explanatory case studies (Chapter VII) found the mathematics tutorials to be inadequate for their needs due to insufficient individual time being available with the person running the tutorial, whereas all of the non-dyslexic students found mathematics tutorials to be adequate for their needs.

Regarding the delivery and assessment of material (Chapter VII), half of the dyslexic students found the delivery of mathematical material to be in an unacceptable format for their needs and 11 of the 12 had encountered problems with assessment procedures. This was significantly different to the non-dyslexic students, where none reported any difficulties with the delivery of material and only two with assessment procedures. In general, where problems were encountered by the dyslexic students with the delivery of material this was due to the speed of conveyance, which resulted in incomplete or inaccurate notes being taken down. Concerning assessment procedures there were notable differences cited amongst the dyslexic students. In the main, the forms of
assessment that were considered, by the dyslexic students, to be unfair and problematic were CAA and multiple-choice examinations. It is also important to note that whilst two of the non-dyslexic students reported difficulties with multiple-choice examinations, of the ten who did not believe any form of assessment to be unfair, six of them mentioned that they believed CAA testing to being cruel and unforgiving.

11.2.3 Research Question 3

This question asked ‘What is the extent, in UK HE, of the provision of mathematics support, and mathematics support for dyslexic students?’

In 2003 the author of this thesis determined that over 65% of universities in the UK offered some form of mathematics learning support over and above that provided by timetabled tutorials, personal tutor groups and problem classes. Furthermore, there were nine universities who were either planning to open some form of mathematics support or would like to do so but were prevented from this due to funding issues.

Regarding specific mathematics support for dyslexic students, it is evident that there is a real need for this support. This has been verified by support workers at several institutions recognising that dyslexic students may need additional support with mathematics. Unfortunately, it was determined that only 13 of the 51 responding universities offer one-to-one specialised mathematics support for dyslexic students.

11.2.4 Research Question 4

This question asked ‘Is the Mathematics Learning Support Centre at Loughborough University providing the level of support that is required for both dyslexic and non-dyslexic students?’ It was determined that the majority of non-dyslexic students were able to obtain the level of help they required from visiting the MLSC. The findings from Chapters VI, VII and IX determined that the drop-in support at the MLSC is likely to be inadequate for the needs of dyslexic students.
11.3 Recommendations

From the case study of the MLSC it became evident that there were instances arising where lecturers were either not aware of, or failed to recognise, the weak mathematical background of some students attending the Centre. Consequently, these students did not receive the basic level of mathematical support that they required. This occurred with students registered on degree programmes other than mathematics. To maximise the support that students receive, it is suggested that teachers are employed within the Centre to assist students undertaking a science foundation course or courses within the Business School and Social Sciences. Lecturers employed in the Centre should be giving support, beyond the level of that encountered in school mathematics. However, it is pertinent to mention that current recruitment policy has resulted in some students now being accepted onto courses without having GCE A Level Mathematics whereas previously this was a course requirement. This is particularly prevalent in engineering; therefore, lecturers should, when assisting engineering students, first ascertain whether or not they have undertaken GCE A Level Mathematics or an equivalent qualification. Once this has been established it will enable help to be given at an appropriate level.

It is considered that lecturers who work in the MLSC should undertake a Professional Development Course designed to raise awareness of the different learning styles of individual students and the needs of students with SpLD’s.

Another important area that has implications for the effective provision of additional mathematics support is that those employed to deliver it wish to do so. The staff census revealed that whilst 27/29 of those completing it wanted to work in the MLSC it is of some concern that there were 2 members of staff employed in the Centre who did not wish to work in it. It is important, not only within the MLSC but throughout the sector, that staff who are employed to provide this form of mathematical support want to do so and are not undertaking this as a result of departmental pressure or to fulfil their timetabled teaching obligations.

Additionally, there were occasions, reported by both staff and students, where initial failure to understand an explanation was due to the mathematical background of the student being weaker than was first apparent. In many of these cases the problem was
identified to be lack of ability with algebraic manipulation. With this lack of algebraic skill being evident amongst many students it is recommended that a compulsory timetabled algebra course, provided by the MEC, is introduced for first year engineering and physics students with a mathematics qualification lower than GCE A Level Grade C or equivalent. This course should culminate with a written examination. It should also be compulsory for students to pass this examination; students who fail should be obliged to retake the examination until they achieved the required result. It is recognised that weaker students would be faced with a more demanding timetable, but is considered important that upon graduation students should be cognisant with the range of skills that are expected of them.

For those dyslexic students who have been awarded individual tutorial support there is, throughout the HE sector, provision of support with topics such as writing skills, time management and revision techniques. However, for those students who are experiencing difficulties with the mathematical or statistical elements of their courses specialist support is not available in many UK universities. To comply with current legislation it strongly recommended that HE institutions make available suitable and adequate support in this area.

It is important that material is presented in a dyslexia-friendly manner, for example comments were made by dyslexic students concerning multiple-choice examinations where the boxes on the answer sheets were so close together that mistakes were made. Another problematic area was that of the examination answer booklets where dyslexic students mentioned the number of times they had to turn pages due to either their large writing or the spacing out of their work. This frequent page turning led to the risk of transcription errors and also excessive time being spent on checking work. It is suggested that more thought is given to the spacing on multi-choice forms; clarity should not be sacrificed for economy of paper. Consideration should also be given to the answer booklets that are provided in examinations; one suggestion is that students are provided with loose numbered sheets, whereby they could write on one side only and easily move from page to page.
11.4 Suggestions for Further Research

The pilot study undertaken to determine whether CAA discriminates against dyslexic students, and the effects that different media combinations might have on both dyslexic and non-dyslexic students, proved to be inconclusive. To comply with the SENDA legislation it is imperative to ascertain that dyslexic students are not disadvantaged when compared to non-dyslexic students. It is suggested that a large-scale study be undertaken in the area of CAA. There is also growing use of CAL and it is also suggested that research in this area is undertaken.

An area of research that may benefit dyslexic students in HE, and those involved with supporting them, is an investigation into the difficulties that are encountered in HE by students who are diagnosed as dyslexic at school or college compared to those who are diagnosed after entering university. This comparison would determine whether compensatory strategies learned in earlier education are transferable to the HE sector and if there are aspects encountered in HE study for which compensatory strategies have not previously been developed. Support workers could then prioritise and focus their early support, to incoming dyslexic undergraduates, on areas where compensatory strategies may need to be developed.

Through the exploratory and explanatory multiple-case studies, and the provision of one-to-one support it has been determined that, in many cases, certain items provided to dyslexic students through the DSA are not being used. With the growing number of dyslexic students in HE claiming the DSA and the large amount of taxpayers' money involved, it is of importance that a large-scale investigation into the realistic needs of these students, which are likely to be course dependent, is undertaken. Many of the students participating in this research found the provision of one-to-one support to be highly beneficial and certain software to be superfluous. If it could be determined, on a larger scale, that this is indeed the case, then the DSA could be apportioned differently to ensure that students in receipt of this allowance are given the support most suited to their needs.

In summary, it appears that throughout the HE sector there is scope for much improvement in the provision that is made for dyslexic students.
References


DEPARTMENT FOR EDUCATION AND SKILLS (DfES). (2004). *The Department for Education and Skills’ response to Professor Adrian Smith’s Inquiry into Post-14 Mathematics Education*. DfES Publications, PO Box 5050, Sherwood Park, Annesley, Nottingham, UK.


DYSEXIA INFORMATION AT LOUGHBOROUGH UNIVERSITY. Information available via the World Wide Web at http://www.lboro.ac.uk/disabilities/pages/practices-dyslexia.html [Accessed on 01/04/07].


DYSEXSIM – A simulation of the visual difficulties that may be experienced by the dyslexic population. Information available via the World Wide Web at http://www-staff.lboro.ac.uk/~cvnbl/dyslexsim/ [Accessed on 01/04/07].


GOVERNMENT RESPONSE TO THE CLAIM PUT FORWARD IN A CHANNEL 4 DISPATCHES PROGRAMME – Information available via the World Wide Web at http://politics.guardian.co.uk/commons/story/0,9061,1661993,00.html [Accessed on 01/04/07].


IMAGES OF THE BRAIN – Downloaded from Google Images.


MATHEMATICS EDUCATION CENTRE AT LOUGHBOROUGH UNIVERSITY. Information available via the World Wide Web at http://mec.lboro.ac.uk/ [Accessed on 08/03/07].

THE MATHEMATICS LEARNING SUPPORT CENTRE AT LOUGHBOROUGH UNIVERSITY. Information available via the World Wide Web at http://mlsc.lboro.ac.uk [Accessed on 31/03/07].


RED BRICK UNIVERSITIES – Information on the origination of the phrase via the World Wide Web at http://www.liv.ac.uk/gradschool/lifeliv.htm [Accessed on 08/03/07].


THE SPACE PROJECT – Inclusive approaches to assessment. Details available via the World Wide Web at http://www.space.ac.uk [Accessed on 05/03/07].


STUDENTS WITH ADDITIONAL NEEDS (SWAN) AT LOUGHBOROUGH UNIVERSITY. Information available via the World Wide Web at http://www.lboro.ac.uk/disabilities/pages/SWAN.htm [Accessed on 01/04/07].


TOMLIN, A. (2003). To Serif or not? A question of fonts. Adults Learning Maths Newsletter, 19, pp1,5. Responses to this question are available from alison.tomlin@kcl.uk.


APPENDIX A: The Exploratory Case Studies

A.1 Student Consent Form

Case studies relating to dyslexia and mathematics are being undertaken by Glynis Perkin at Loughborough University as part of her PhD research. These studies are investigating how dyslexia impedes the learning and understanding of mathematics, how dyslexic students might be disadvantaged in their learning and understanding of mathematics in HE and how they might be best supported. The results of these case studies will be included in the thesis that will be submitted and may also be published externally. Students may withdraw from this research at any time prior to June 2006.

Participants are assured that:

- Their real identity will not be disclosed, i.e., they will be given a pseudonym.
- Opportunity will be given to each participant for them to verify that what has been written, as a result of the interview(s), is correct.

Name of student (please print): ..............................................................

I have voluntarily agreed to participate in the above-described case studies.

I agree/ do not agree that Glynis Perkin may view my report from the Educational Psychologist.

I agree/ do not agree that Glynis Perkin may speak to members of staff who know me in the MLSC/ the ELSU/ the DANS to further establish any areas of difficulty that I have encountered and any compensatory strategies that I have developed.

Signature: ............................................................
Date: ............................................................
A.2  Research Design

<table>
<thead>
<tr>
<th>Question</th>
<th>What problems, if any, do students who have been diagnosed as dyslexic, after commencing their undergraduate studies, experience in mathematics?</th>
</tr>
</thead>
</table>
| Purpose  | (1) To determine whether these students are impeded in their learning and understanding of mathematics as a direct result of dyslexia.  
(2) To determine whether there is evidence to justify a larger, more detailed study.  
(3) To provide training for the researcher in undertaking case study research. |
| Unit of Analysis | The unit of analysis is a student and is holistic. |
| Linking Data to Purpose | In each of the case studies information from several sources is matched to Purpose 1. The outcome of Purpose 1 will determine Purpose 2. |
| Criteria for Interpreting the Findings | Inspection of the findings to determine whether there is sufficient evidence to suggest that these students are impeded in their learning and understanding of mathematics. |

A.3  Protocol

A.3.1  Introduction to and Purpose of the Exploratory Case Studies

Exploratory multiple-case studies, in which the unit of analysis is a student, are being undertaken by Glynis Perkin, at Loughborough University to determine whether dyslexic students are impeded in their learning and understanding of mathematics as a direct result of their dyslexia.

Each case will involve a student from the faculty of engineering or the faculty of science, who has been diagnosed as dyslexic after commencement of their undergraduate studies. These students will, thus, not have been taught any compensatory strategies. All participating students will be assured anonymity and given pseudonyms. A member of the ELSU has agreed to ask students who match the criteria if they will be willing to participate in this research.
The purpose of these studies is to determine whether there is any evidence to suggest that dyslexic students are impeded in their learning and understanding of mathematics as a direct result of their dyslexia. Additionally these exploratory studies will provide training in the use of case study for the researcher. If there is evidence to suggest that students are impeded in their learning and understanding of mathematics as direct result of their dyslexia then subsequent studies will be undertaken. These will be explanatory, the aim will be to determine the specific areas of mathematics in which dyslexic students are impeded and if there are problems encountered with the delivery and assessment of mathematical material.

A.3.2  Data Collection Procedures

To enable verification through triangulation, each case study will involve data being obtained by two interviews with the student, by viewing the report from the EP (provided permission to do so is given) and by interviewing a member of staff who knows the student.

The interviews with the students will be of a semi-structured format. Permission will be sought from each student to allow their EP reports to be viewed by the researcher, and members of staff who know the student to be contacted. After the interviews have been undertaken, a further meeting will be arranged and the students will be asked to verify that what has been written is correct.

The members of staff, at Loughborough University, who will be consulted are employed in the MLSC, the ELSU or the DANS.

All the raw data will be filed under the given pseudonyms and will be available for inspection if required.
A.3.3  The Exploratory Case Study Question

The question being addressed is, ‘What problems, if any, do students who have been diagnosed as dyslexic, after commencing their undergraduate studies, experience in mathematics?’

The interview questions that will be posed to each student are given in section A.5.

The member(s) of staff who had contact with these students will be asked to describe the student and his/her difficulties and compensatory strategies.

A.3.4  The Exploratory Case Study Report

The case study report will be written for academic or academic related members of staff in HE who teach or lecture mathematics, or support students in this subject. The report will contain information from the interview with the students, a précis of the reports from the EP (if permission was given to view this document) and the information obtained from members of staff who know the students. A table will be included showing each student and the difficulties they encountered.

A.4  Criteria for Judging the Quality of the Research Design

A.4.1  Construct Validity

1. Use of multiple sources of evidence for each case.

2. Verification, by each participant, that what has been written as a result of the interviews is correct.

3. To establish a chain of evidence that will enable a reader of the report to follow through all the stages of the case study.
A.4.2 External Validity

1. The use of multiple-cases, which have been chosen to replicate each other, provide stronger support for generalisation.

A.4.3 Reliability

1. Details of the study may be viewed in the case study protocol.

2. The most significant points from the data are presented in a table and all raw data are available for inspection.

3. The aim is to enable another researcher to repeat the procedures that have been undertaken and arrive at the same results.

A.5 Interview Questions

A.5.1 Initial Interview Questions

1. What course are you undertaking and what year of study are you in?
2. What were your GCSE and GCE A Level results?
3. When did you become aware that you were finding some areas of study difficult?
4. In what areas were these difficulties experienced?
5. How did you feel about this?
6. What made you suspect that you might be dyslexic?
7. After being diagnosed as dyslexic how did you feel?
8. What help have you had?
9. Was this help adequate?
10. Have you used the MLSC?
11. Did the MLSC help you?
12. What sort of difficulties have you encountered with mathematics?
13. How do you feel about other people knowing that you are dyslexic?
A.5.2 Additional Interview Questions - asked at the 2nd interview

14. What is your preferred style of lecture delivery?
15. Can you play chess and/or read music?
16. Do you use mind maps?
17. Which was most helpful, the dyslexia support or the one-to-one mathematics support (if relevant)?
APPENDIX B: The ‘One-to-One’ Case Studies

B.1 Student Consent Form (See Appendix A, section A.1).

B.2 Research Design

<table>
<thead>
<tr>
<th>Questions</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) How does dyslexia impede the learning and understanding of mathematics for engineering students in HE?</td>
<td>1) Dyslexic students experience difficulties with note taking.</td>
</tr>
<tr>
<td>b) How can dyslexic students be helped to overcome their mathematical difficulties?</td>
<td>2) Dyslexic students experience difficulties with multi-stage operations.</td>
</tr>
<tr>
<td></td>
<td>3) Some dyslexic students experience visual problems, which result in difficulties being encountered when working with rows/columns of figures and equations.</td>
</tr>
<tr>
<td></td>
<td>4) Dyslexic students encounter difficulties with lengthy descriptive text.</td>
</tr>
<tr>
<td></td>
<td>5) Dyslexic students experience difficulties with the application of notation and the recall of formulae.</td>
</tr>
<tr>
<td></td>
<td>6) Drop-in support at the Mathematics Learning Support Centre is inadequate for dyslexic students.</td>
</tr>
<tr>
<td></td>
<td>7) Dyslexic students may be helped to overcome their mathematical difficulties</td>
</tr>
</tbody>
</table>

Unit of Analysis: The unit of analysis is a student and is holistic.

Linking Data to Hypotheses: Cross case synthesis will be undertaken. In each of the case studies information from several sources will be matched to the hypotheses.

Criteria for Interpreting the Findings: Inspection of the findings to justify whether there is sufficient evidence for the acceptance or rebuttal of each of the hypotheses and to determine the ways in which dyslexic students are impeded in their learning and understanding of mathematics.

B.3 Protocol

B.3.1 Introduction to and Purpose of the ‘One-to-One’ Case Studies

During the three years of this research dyslexic engineering students have been supported with their mathematics modules by the researcher. This has enabled any difficulties that have been encountered to be witnessed and support mechanisms to be
developed and tested. The purpose being to determine how dyslexic students are impeded in their learning and understanding of mathematics, how these students might be disadvantaged by current practices of delivery and assessment within Loughborough University and how they might be assisted. The findings from these in-depth studies will also be matched to the findings from the explanatory multiple case studies, if the findings are in agreement this will provide additional internal validity. Additionally, the findings from the interview questions and the discussions with the students will be checked against the observations made by the researcher. A number of hypotheses have been stated and these may be viewed in the research design (section B.2).

The two case studies were undertaken with undergraduate students from engineering departments who had been awarded one-to-one tutorial support in mathematics for one hour per week. The students have been assured anonymity and been given or chosen pseudonyms.

B.3.2 Data Collection Procedures

To enable verification through triangulation, each case study will involve data being obtained by interviewing the student, by discussions with the student, by working with the student (observation), by viewing the report from the EP (if permission to do so is given), by consultation with a member of staff who knows the student and by developing and testing support mechanisms.

The interviews with the students, during which notes will be taken, will be of a semi-structured format, Discussion relating to particular areas of difficult and ways of addressing these difficulties will also be recorded. The students will be asked to verify that what has been written is correct.

The members of staff who will be consulted are employed in the MLSC, the ELSU or the DANS.

All the raw data will be filed under the given or chosen pseudonym and will be available for inspection if required.
B.3.3 The ‘One-to-One’ Case Study Questions

The questions being addressed are:

- How does dyslexia impede the learning and understanding of mathematics for students in HE?
- How are dyslexic students disadvantaged in their learning and understanding of mathematics?
- How can dyslexic students be helped to overcome their mathematical difficulties?

The interview questions (section B.5) build upon those asked in the exploratory studies and, to some extent, were developed through working with Patrick. These questions are asked to Peter (One-to-One case study 2, section 6.2.1) and the dyslexic students participating in the explanatory case studies (see Chapter VII). The control group of non-dyslexic students participating in the explanatory studies (see Chapter VII) were also posed the relevant questions, which are clearly identified.

The members of staff who have had contact with these students will be asked to give details appertaining to their difficulties and coping strategies.

B.3.4 The ‘One-to-One’ Case Study Report

The case study report will be written for academic or academic related members of staff in HE who teach or lecture mathematics, or support students in this subject. The report will contain information from the interviews with the students, the discussions with the students, observations of the difficulties encountered by the students, a précis of the reports from the EP (if permission was given to view this document) and information from members of staff relating to the difficulties encountered by the student and any compensatory strategies they developed. The support mechanisms that have been provided will be discussed in detail.
B.4 Criteria for Judging the Quality of the Research Design

B.4.1 Construct Validity

1. Multiple sources of evidence will be used for each case.

2. Verification, by each participant, that what has been written as a result of the interview and any subsequent discussions is correct.

3. To establish a chain of evidence that will enable a reader of the report to follow through all the stages of the case study.

B.4.2 Internal Validity

1. Cross case synthesis will be used to link the findings of each case study to the hypotheses.

2. These case studies will be compared to the explanatory case studies (Chapter VII), if similar findings are obtained this will increase internal validity.

B.4.3 External Validity

1. The use of multiple-cases, which have been chosen to replicate each other, provides stronger support for generalisation.

B.4.4 Reliability

1. Details of the study may be viewed in the case study protocol.
2. The relevant details from the data will be pattern matched to the findings from the explanatory case studies (Chapter VII) and all raw data are available for inspection.

3. The aim is to enable another researcher to repeat the procedures that have been undertaken and arrive at the same results.

B.5 Interview Questions

The questions posed to Peter (one-to-one case study 2, section 6.2.1) are identical to those asked in the Explanatory Studies and may be viewed in Appendix C.6.
APPENDIX C: The Explanatory Studies

C.1 Student Consent Form (See Appendix A, section A.1).

C.2 Student Payment Form

Explanatory Case Study

Dyslexia and Mathematics

Name: 

Student I.D. Number: 

Address: 

I have today received £5.00 for participating in this study:

Signature: .................................................................

Date: ..................................................

Authorised by: .................................................................
### C.3 Research Design

<table>
<thead>
<tr>
<th>Questions</th>
<th>Hypotheses</th>
</tr>
</thead>
</table>
| a) How does dyslexia impede the learning and understanding of mathematics for engineering students in HE?  
b) How are dyslexic engineering students disadvantaged by current practices of material delivery and examination procedures within Loughborough University? | 1) Dyslexic students experience difficulties with note taking.  
2) Dyslexic students experience difficulties with multi-stage mathematical operations.  
3) Some dyslexic students experience visual problems, which result in difficulties being encountered when working with rows/columns of figures and equations.  
4) Dyslexic students encounter difficulties with lengthy descriptive text.  
5) Dyslexic students experience difficulties with the application of notation and recall of formulae.  
6) Tutorial support is inadequate for the problems experienced by dyslexic students.  
7) Drop-in support at the Mathematics Learning Support Centre is inadequate for the needs of dyslexic students.  
8) Some methods of mathematics delivery and assessment are unfair to dyslexic students.  
9) Dyslexic students learn and revise differently to non-dyslexic students.  
10) Dyslexic students may understand some areas of mathematics but obtain incorrect answers. |

<table>
<thead>
<tr>
<th>Unit of Analysis</th>
<th>The unit of analysis is a student and is holistic.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linking Data to Hypotheses</td>
<td>Cross-case synthesis will be undertaken. In each of the case studies information from several sources will be matched to the hypotheses.</td>
</tr>
<tr>
<td>Criteria for Interpreting the Findings</td>
<td>Inspection of the findings to justify whether there is sufficient evidence for the acceptance or rebuttal of each of the hypotheses and to determine the ways in which dyslexic students are impeded in their learning and understanding of mathematics.</td>
</tr>
</tbody>
</table>
C.4 Protocol

C.4.1 Introduction to and Purpose of the Explanatory Case Studies

During the second and third years of this research explanatory multiple-case studies, in which the unit of analysis is again a student, were undertaken. The purpose being to determine how dyslexic students are impeded in their learning and understanding of mathematics and how these students might be disadvantaged by current practices of delivery and assessment within Loughborough University. A number of hypotheses have been stated and these may be viewed in the research design (Appendix C.3).

Each case study involves an undergraduate student from an engineering department. All participating students have been assured anonymity and chosen, or been given, pseudonyms. A member of the ELSU has agreed to forward an email from the researcher to all dyslexic students, who did not participate in the exploratory study and match the criteria, asking if they will be willing to participate in this research. A control group of non-dyslexic undergraduate engineers will also be interviewed. This control group will be used to determine whether there is evidence of differences in approach to study and revision between the two groups and whether there are particular areas of mathematics that prove more problematic to dyslexic students.

C.4.2 Data Collection Procedures

To enable verification through triangulation, each dyslexic case study will involve data being obtained by interviewing the student, by viewing the report from the EP (if permission to do so is given) and by consultation with a member of staff who knows the student.

The interviews with the students, during which notes will be taken, will be of a semi-structured format. The students will subsequently be asked to verify that what has been written is correct.
The members of staff who will be consulted, are employed in the MLSC, the ELSU or the DANS.

All the raw data will be filed under the given or chosen pseudonym and will be available for inspection if required.

C.4.3 The Explanatory Case Study Questions

The questions being addressed are:

- How does dyslexia impede the learning and understanding of mathematics for students in HE?
- How are dyslexic students disadvantaged in their learning and understanding of mathematics?

The interview questions that will be posed to each student are given in section C.6.

The members of staff who have had contact with these students will be asked to describe the difficulties encountered and any compensatory strategies they developed.

C.4.4 The Explanatory Case Study Report

The case study report will be written for academic or academic related members of staff in HE who teach or lecture mathematics, or support students in this subject. The report will contain information from the interviews with the dyslexic and non-dyslexic students. For the dyslexic students a précis of the reports from the EP (if permission was given to view this document) and information from members of staff relating to the difficulties encountered and compensatory strategies will be included. For the non-dyslexic students only details from the interviews will be given. For each hypothesis a table will be included showing the findings from both the dyslexic case studies and the non-dyslexic interviews. The hypotheses will then be accepted or rejected.
C.5 Criteria for Judging the Quality of the Research Design

C.5.1 Construct Validity

1. Multiple sources of evidence will be used for each case.

2. Verification, by each participant, that what has been written as a result of the interview is correct.

3. To establish a chain of evidence that will enable a reader of the report to follow through all the stages of the case study.

C.5.2 Internal Validity

1. Cross case synthesis will be used to link the findings of each case study to the hypotheses.

2. Multiple-case studies with both dyslexic and non-dyslexic students are being undertaken to minimise any pattern matching, which might occur, due to non-dyslexic factors.

3. The findings from the explanatory case studies will be correlated against the findings from the ‘One-to-One’ case studies.

C.5.3 External Validity

1. The use of multiple-cases, which have been chosen to replicate each other, provides stronger support for generalisation.
C.5.4 Reliability

1. Details of the study may be viewed in the case study protocol (Appendix C.4).

2. The relevant details from the data are presented in tables and all raw data are available for inspection.

3. The aim is to enable another researcher to repeat the procedures that have been undertaken and arrive at the same results.

C.6 Interview Questions

All the questions were posed to the dyslexic students. The questions that were posed to the non-dyslexic students are those with the question number in bold font.

1. What course are you undertaking and what year of study are you in?
2. Which GCE A Levels (or equivalent) did you take and what were your results?
3. What made you suspect that you might be dyslexic?
4. Whilst at university have you encountered any general difficulties that impeded your study?
5. In what areas were these difficulties experienced?
6. Do you have an up-to-date set of notes for your mathematics modules?
7. If not, why not?
8. If so, were these notes taken by you in the lecture or obtained from elsewhere (please detail where)?
9. What help have you had as a result of being diagnosed as dyslexic?
10. Was this help adequate?
11. If not, in what ways did the help given fail to address your problems?
12. Do you use the software (if this has been provided)?
13. If not, why not?
14. Are there any areas of mathematics or particular topics that you are experiencing/have experienced difficulties with?
15. If so can you describe them?
16. Are there any areas of mathematics that you understand but frequently obtain the wrong answer for?
17. How would you describe the speed at which mathematics topics in lectures are delivered?
18. Do the mathematics tutorials address any difficulties that you encounter?
19. If not, why not?
20. Have you visited the Mathematics Learning Support Centre on a drop-in basis?
21. Is the drop-in support at the MLSC adequate for your needs?
22. If not, have you any idea why the available support was inadequate for you needs?
23. Are you willing for academic and academic related staff to know that you are dyslexic?
24. What medium of delivery of mathematical material are you most easily able to work with?
25. Is the delivery of mathematical material in the format you would like?
26. If not, what styles are particularly difficult and why?
27. Have you encountered any forms of testing that have proved particularly difficult?
28. Do you use mind maps for mathematics?
29. What was most helpful, the dyslexia support or the one-to-one mathematics support (if relevant)?
30. Have you been given coloured overlays?
31. If so, do you use them?
APPENDIX D: Trial of CAA Material

D.1 Student Payment Form

Trial of Computer Assisted Assessment Material

Name: ____________________________

Student ID Number: ________________

Address: __________________________

Postcode: __________________________

National Insurance Number: __________

Amount of money to be paid to student = £5.00

Signature of Student: ______________________

Authorised by: ________________________

- 367 -
### D.2 Personal Details

**Trial of Computer Assisted Assessment Material**

<table>
<thead>
<tr>
<th>Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I.D. Number</td>
<td></td>
</tr>
<tr>
<td>Age:</td>
<td></td>
</tr>
<tr>
<td>Gender:</td>
<td></td>
</tr>
</tbody>
</table>

What is your highest qualification in mathematics and what grade did you obtain?

How long ago did you obtain this qualification?

Do you have a Specific Learning Difficulty?

If so, please specify

---

Now select the computer test

**‘HEA-HELM-DDIG TRIALS: Integration’**
D.3 Post-test Questionnaire

Trial of Computer Assisted Assessment Material

Name: __________________________

I.D. Number: _____________________

Please answer each question by placing a tick in ONE of the options and adding comments where required

1. Do you feel that computer assisted tests give a realistic indication of your ability?
   Yes [ ] If yes, why?
   No [ ] If not, why?

2. In previous computer assisted tests, how many times, on average, have you referred to each displayed question during your calculation of it?

3. Are you willing to be contacted at a later date to discuss this trial test?
   Yes [ ]
   No [ ]

Media Combination used: (a) Text Only [ ] Go to Section A
                        (b) Text and Diagram [ ] Go to Section B
                        (c) Text and Audio [ ] Go to Section C
Section A: ‘Text Only’ Users

4a. ‘Text only’ representation helped me to understand what the questions were asking.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5a. ‘Text only’ representation helped me to recall the method required.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6a. ‘Text only’ representation helped me to calculate the answers on paper.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7a. How many times, on average, did you refer to each displayed question during your calculation of it?  

8a. Overall, did you find that the ‘text only’ representation:

Aided your performance?  

Impaired your performance?
Section B: ‘Text and Diagram’ Users

4b. ‘Text and diagram’ representation helped me to understand what the questions were asking.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5b. ‘Text and diagram’ representation helped me to recall the method required.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6b. ‘Text and diagram’ representation helped me to calculate the answers on paper.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7b. How many times, on average, did you refer to each displayed question during your calculation of it?  

8b. Overall, did you find that the ‘text and diagram’ representation:

Aided your performance?  

Impaired your performance?  

9b. Did you prefer the ‘text and diagram’ representation to that of text only?

Yes  

Don’t know  

No  

10b. Comments
Section C: ‘Text and Audio’ Users

4c. ‘Text and audio’ representation helped me to understand what the questions were asking.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5c. ‘Text and audio’ representation helped me to recall the method required.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6c. ‘Text and audio’ representation helped me to calculate the answers on paper.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7c. How many times, on average, did you listen to each displayed question during your calculation of it? __________

8c. Overall, did you find that the ‘text and diagram’ representation:

- Aided your performance? __________
- Impaired your performance? __________

9c. Did you prefer the ‘text and audio’ representation to that of text only?

- Yes __________
- Don’t know __________
- No __________

10c. Comments __________
APPENDIX E: Mathematics Support in HE

E.1 E-mail sent to the Universities Selected for the Survey

Provision of Mathematics Learning Support in the UK

Dear

In 2000 the LTSN Maths, Stats & OR Network conducted a survey of the extent to which universities were providing mathematics support over and above normal lecturing/tutorial support. The results have been published in two parts in MSOR Connections, Volume 1, Number 3: August 2001 and Volume 2, Number 1: February 2002.

Following up this survey, I am updating the information about learning support for mathematics in the Higher Education sector of Great Britain. This is in connection with a research project being conducted by the Mathematics Learning Support Centre at Loughborough University.

It would be greatly appreciated if you could respond by informing me whether or not there exists learning support for mathematics at your institute. If so, could you provide me with a contact name, and address (e-mail URL).

Your co-operation in this survey is appreciated.

Yours sincerely,

Glynis Perkin
E.2 Consent Form for the Universities that were Visited

Do you require your institution to remain anonymous? YES/ NO*

Are you willing/ not willing* for me to take photographs of your mathematics centre and use them in my thesis and/ or publications?

* Please delete as applicable

Name of Institution (please print)..................................................................

Name (please print)........................................................................................

Signature..........................................................................................................

E.3 Questions Posed to the Universities that were Visited

Title and Location of Mathematics Centre

<table>
<thead>
<tr>
<th>When was the Centre opened?</th>
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</table>

- 374 -
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What prompted its opening?</td>
<td></td>
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<tr>
<td>What facilities were available when it first opened?</td>
<td></td>
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<tr>
<td>What facilities are available now?</td>
<td></td>
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<tr>
<td>Question</td>
<td>Answer</td>
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<td>-------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
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<tr>
<td>How is it Funded?</td>
<td></td>
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<tr>
<td>What are the current opening hours?</td>
<td></td>
</tr>
<tr>
<td>How is it Staffed?</td>
<td>(e.g. dedicated mathematics academic staff, postgraduates).</td>
</tr>
<tr>
<td>Who is allowed to use the centre?</td>
<td></td>
</tr>
<tr>
<td>Do you feel that the service provided is adequate for the needs of the students?</td>
<td></td>
</tr>
<tr>
<td>If not, why not?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
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<tr>
<td>------------------------------------------------------------------------</td>
<td>--------</td>
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<tr>
<td>What additional facilities would you like to provide?</td>
<td></td>
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<tr>
<td>Have you noticed an increase in the usage of the centre?</td>
<td></td>
</tr>
<tr>
<td>If so, since when?</td>
<td></td>
</tr>
<tr>
<td>Do you provide any specific mathematics support for students with dyslexia?</td>
<td></td>
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<tr>
<td>If so, what?</td>
<td></td>
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<tr>
<td>Do you feel that there is a need for this?</td>
<td></td>
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<td>-------------------------------------------</td>
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<tr>
<td>If so, why?</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Do you give diagnostics testing to students undertaking mathematics modules on entry?</th>
</tr>
</thead>
<tbody>
<tr>
<td>If so, do you follow up those students that are deemed to be at risk?</td>
</tr>
<tr>
<td>How do you do this?</td>
</tr>
<tr>
<td>Staff Development:</td>
</tr>
<tr>
<td>-------------------</td>
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<tr>
<td>Observations:</td>
</tr>
</tbody>
</table>
Dear

I am in the final year of my postgraduate research, which is investigating both mathematics support and the difficulties encountered by dyslexic students with mathematics in HE.

In 2003 Tony Croft and myself conducted a survey of the extent to which universities were providing mathematics support over and above normal lecturing/tutorial support. The results of which have been published in MSOR Connections, Vol. 4, No. 2, May 2004.

Following up this survey I am now updating the information about learning support for mathematics in the HE sector of the UK to include dyslexia. Whilst all HE Institutions have departments that support students with disabilities, I am endeavoring to ascertain whether any of the universities that offer mathematics support also provide specialist mathematical help for dyslexic students who are entitled to additional tutorial support.

It would be greatly appreciated if you could respond by informing me whether or not there exists a member of staff in your mathematics support area with expertise in supporting students with dyslexia. If so do they provide one-to-one support in mathematics to dyslexic undergraduates?

If so, could you provide me with a contact name, and address (e-mail URL). Individual institutions will remain anonymous.

Your co-operation in this survey will be greatly appreciated.

Yours sincerely,

Glynis Perkin
## APPENDIX F: The Mathematics Learning Support Centre
### Case Study

#### F.1 Research Design

<table>
<thead>
<tr>
<th>Questions</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) How effective is the MLSC?</td>
<td>1) Students use the MLSC for all semester, not just for help with coursework and past examination papers.</td>
</tr>
<tr>
<td>b) How effective is the drop-in support for students with dyslexia?</td>
<td>2) Staff and students are aware of the range of support that is provided by the MLSC.</td>
</tr>
<tr>
<td>c) How necessary is the MLSC?</td>
<td>3) The MLSC helps students to understand the mathematical content of their programme of study.</td>
</tr>
<tr>
<td></td>
<td>4) Staff working in the MLSC have an understanding of the difficulties associated with dyslexia and are able to recognise students who might be dyslexic.</td>
</tr>
<tr>
<td></td>
<td>5) The MLSC provides suitable drop-in support for dyslexic students.</td>
</tr>
<tr>
<td></td>
<td>6) The mathematical background of many students is inadequate for university level mathematics.</td>
</tr>
<tr>
<td></td>
<td>7) There is a need for the MLSC on academic grounds.</td>
</tr>
<tr>
<td></td>
<td>8) There is a need for the MLSC on economic grounds.</td>
</tr>
</tbody>
</table>

### Unit of Analysis

The unit of analysis is the MLSC; embedded units are the students who use the Centre and the academic and academic related staff who are employed in the Centre.

### Linking Data to Hypotheses

Cross-case synthesis between the embedded units of analysis will be undertaken. Information from several sources will be matched to the hypotheses.

### Criteria for Interpreting Findings

Inspection of the findings to justify whether there is sufficient evidence for the acceptance or rebuttal of each of the hypotheses will be undertaken.
F.2 Protocol

F.2.1 Introduction to and Purpose of the MLSC Case Study

The MLSC at Loughborough University was opened in 1996. This is the first time, since its inception, that an in-depth large-scale investigation into the need for it, and its effectiveness, has been undertaken. The purpose of this single-case explanatory study is to determine how effective the MLSC is, how adequate the support is for dyslexic students and if this form of support is really needed. The unit of analysis is the MLSC; embedded units of analysis are the students who use the Centre and the staff who are employed in the Centre. A number of hypotheses have been stated and these may be viewed in the research design (Appendix F.1).

The case study will include:

- Observation by the researcher
- Distribution of census forms to all academic and academic related staff in the School of Mathematics
- Distribution of questionnaires to students who frequently use the Centre

A small pilot study will be undertaken with the staff census form, this will enable modifications, if shown to be necessary, to be made prior to distribution of the forms. The census forms and questionnaires contain many questions, some of which are outside the area of this research. The findings from these questions will be published elsewhere in due course. These questions were included due to the possibility of an additional Centre and/or expansion to the existing Centre taking place and it was not considered viable to ask staff and students to complete two forms.

From this study it will be possible to identify the effectiveness of the Centre for both dyslexic and non-dyslexic students. This study will also provided a ‘benchmark’ that can be used to investigate the effectiveness of any changes that may be recommended and any additional services that may be provided in the future.
**F.2.2 Data Collection Procedures**

To enable verification through triangulation, the case study will involve data being obtained by observation, from census forms completed by staff in the School of Mathematics and questionnaires completed by students who frequently use the Centre. A covering letter will be attached to the staff census forms explaining the purpose of the research and the forms will be hand delivered to each member of staff. It is recognised that dyslexic students who use the Centre may not wish to complete the lengthy questionnaire, however, students who participated in the explanatory studies and the ‘one-to-one support’ case studies were asked question about the MLSC and information from these studies will be included in the Case Report.

All the raw data that is obtained will be filed and available for inspection if required.

**F.2.3 The MLSC Case Study Questions**

The questions being addressed are:

- How effective is the MLSC?
- How effective is the support for students with dyslexia?
- How necessary is the MLSC?

The staff census forms and student questionnaires are shown in sections F.6 and F.7 respectively.

**F.2.4 The MLSC Case Study Report**

The case study report will be written for academic or academic related members of staff in HE who teach or lecture mathematics, or support students in this subject. The report will contain details of the staff and student responses and will highlight any differences or agreement between them. The report will contain information obtained from observation in the Centre. The information obtained from the earlier ‘One-to-One’ and explanatory case studies regarding the MLSC will also be referred to.
F.3 Criteria for Judging the Quality of the Research Design

F.3.1 Construct Validity

1. Multiple sources of evidence will be used in this case study.

2. To establish a chain of evidence that will enable a reader of the report to follow through all the stages of the case study.

F.3.2 Internal Validity

1. Cross-case synthesis will be used to link the findings from multiple sources to the hypotheses. Additionally pattern matching from the earlier ‘One-to-One and explanatory case studies will also be undertaken.

F.3.3 External Validity

1. Generalisation from a single case study is not automatic, however, the investigator is looking at a specific area, the theory from which may be related to other universities who provide a similar form of support. Where the support available greatly differs from that provided at Loughborough University, the theory will need to be tested by replication of the findings in other institutions.

F.3.4 Reliability

1. Details of the study may be viewed in the case study protocol (Appendix F.2).

2. The relevant details from the data have been collated into an excel spreadsheet prior to analysis, and all raw data are available for inspection.

3. The aim is to enable another researcher to repeat the procedures that have been undertaken and arrive at the same results.
F.4 Letter Accompanying the Staff Census Form

7th December 2004

Dear

The Mathematics Learning Support Centre (MLSC) at Loughborough University is widely regarded throughout the Higher Education sector as delivering excellent university-wide provision of mathematics and statistics support. The Centre has applied to become a HEFCE Centre for Excellence (CETL), the result of which will be known on 17th December 2004. If CETL status is achieved we will see not only a significant injection of funding for mathematics and statistics support across campus but also potential for further development of the MLSC through its raised profile and status.

In a recent survey by Perkin and Croft it was found that out of 106 universities in the UK over 35% of them offer learning support in centres similar to ours, therefore it is important that we continue to offer the best support possible. Since any development has the potential to impact on all lecturers in the Department of Mathematical Sciences it is important that we consult staff in order to determine their views, expectations and the ways in which provision could be enhanced.

This is the first time, since the inception of the MLSC in 1995, that the views of academic and academic related staff in the Department are being sought on matters concerning the Centre. It is now timely to obtain a review of the operation of the MLSC as it enters its 2nd decade, with or without CETL funding.

Additionally, Glynis Perkin is undertaking postgraduate research into the effectiveness of mathematics learning support and the problems encountered by dyslexic engineering students in their mathematics modules. As part of this research, an in-depth case study of the MLSC is being conducted, from which it is hoped to evaluate its effectiveness and also to determine whether the current support is suitable for dyslexic students.

The attached census thus has a dual role and consequently we would be grateful if you could take the time to complete it as thoroughly as possible. We strongly encourage you to take advantage of this opportunity to help determine the future shape and direction of the Centre.

With thanks,

Glynis Perkin
F.5 The Staff Census Form

CENSUS
ON
THE MATHEMATICS LEARNING SUPPORT CENTRE

For Academic and Academic Related Staff in the Department of Mathematical Sciences at Loughborough University

INDIVIDUAL NAMES WILL NOT BE RELEASED

PERSONAL COMMENTS WILL ONLY BE PUBLISHED IN THE FORM OF ‘ACADEMIC STAFF COMMENTED...’

RESULTS OF THIS CENSUS WILL BE AVAILABLE ON REQUEST

Please return your completed form to Glynis Perkin in the envelope provided.

The names of all staff who return their completed census form by 16th December 2004 will be entered into a prize draw for a £20.00 book token, which will take place on 17th December 2004.

ALL STAFF
Section 1: Personal Data
Section 2: General Questions
Section 3: Reasons for having the MLSC
Section 4: Expansion & Development of The Mathematics Learning Support Centre (MLSC)
Section 5: Suggestions

FOR STAFF WHO HAVE WORKED IN THE MLSC
Section 6: Working in the MLSC

Please fill in details/comments or tick the boxes as appropriate

Section 1: Personal Details

1.1 Name

1.2 Which age group are you in? under 35 ☐ 35–45 ☐ over 45 ☐

- 386 -
1.3 What is your academic status?

- Professor
- Reader
- Senior Lecturer
- Lecturer
- University Teacher
- Other, please state

1.4 Have you received any formal training or attended any Professional Development Course to enable you to recognise the symptoms of dyslexia?

- Yes
- No

1.5 Have you worked or are you working in the MLSC on a regular timetabled basis?

- Yes
- No

Section 2: General Questions

2.1 For what proportion of the students whom you encounter do you consider that their undergraduate course started at a higher level than their mathematical background had prepared them for?

<table>
<thead>
<tr>
<th>a) In tutorials/personal tutee groups</th>
<th>b) In the MLSC (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>Almost all</td>
<td>Almost all</td>
</tr>
<tr>
<td>More than half</td>
<td>More than half</td>
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<tr>
<td>About half</td>
<td>About half</td>
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<tr>
<td>Less than half</td>
<td>Less than half</td>
</tr>
<tr>
<td>Almost none</td>
<td>Almost none</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
2.2 For the students whom you encounter, what are their main difficulties in mathematics generally related to?

Please tick all options you consider to be applicable

**a) In tutorials/personal tutee groups**
- A specific question
- A whole lecture
- Pre-university background
- Other, please specify

**b) In the MLSC (if applicable)**
- A specific question
- A whole lecture
- Pre-university background
- Other, please specify

2.3 For the students whom you encounter, what are the main areas in which they have problems with?

Please tick all options you consider to be applicable

**a) In tutorials/personal tutee groups**
- Basic manipulation
- Linear algebra
- Calculus
- Statistics
- Other, please specify

**b) In the MLSC (if applicable)**
- Basic manipulation
- Linear algebra
- Calculus
- Statistics
- Other, please specify

2.4 Do you have any suggestions regarding ways in which students might be helped with their mathematics (other than the MLSC)?
2.5 Do you feel that the MLSC is well located for its purpose?
Yes ☐
No ☐
If not, where do you think that it should be located?

2.6 Are you aware that the MLSC runs a series of lunchtime support sessions?
Yes ☐
No ☐

2.7 On entering the MLSC, what is your impression of it?
Warm and friendly ☐
Neutral ☐
Daunting ☐
Don’t know, never visited it ☐
Other, please specify

2.8 Have you ever used the MLSC to obtain information sheets to distribute to students in your lectures or tutee groups?
Yes ☐
No ☐

2.9 Have you ever consulted staff in the MLSC regarding the GCSE or A-level syllabi?
Yes ☐
No ☐
2.10 Are you aware that the MLSC has a specialist tutor to support students with dyslexia?

Yes  
No

2.11 Have you suspected that any of the students you meet might be dyslexic?

a) In tutorials, personal tutee groups or during project supervision

Yes  If so, how many?  
No

b) In the MLSC (if applicable)

Yes  If so, how many?  
No

If you have answered ‘yes’ to the above question(s)

a) Why?  

b) What action did you take?  

2.12 Are you aware that the MLSC runs a pre-university course, for engineering students with weak or non-traditional mathematical backgrounds?

Yes  
No

2.13 Are you conversant with the 2001 legislation relating to universities and disabled students?

Yes  
Vaguely  
No
2.14 As a member of staff, how do you feel about the current situation, where, on certain courses, students may fail their mathematics modules but still progress through their course?

- That’s how it should be
- Unconcerned
- Slightly concerned
- Very concerned
- Should not be allowed

2.15 Regarding the previous question, how do you think most other academic staff in the department feel about this issue?

☐

2.16 During the current academic year, what proportion of the students that you have encountered do you feel should have been admitted to a degree programme?

a) In tutorials/personal tutee groups

- All
- Almost all
- More than half
- Less than half
- Almost none
- None

b) In the MLSC (if applicable)

- All
- Almost all
- More than half
- Less than half
- Almost none
- None
Section 3: Reasons For Having a Mathematics Learning Support Centre

3.1 Do you believe that the university should provide mathematics support, over and above that provided by lectures and tutorials?

Yes ☐ If so, why

No ☐ If not, why

3.2 What do you believe is the reason for students seeking help with mathematics?

Please tick all options you consider to be applicable

Increased academic level of courses ☐
Decrease in knowledge of incoming students ☐
Increase in the number of dyslexic students ☐
Lowered academic recruitment level ☐
Students today demand / expect more support ☐
Other, please specify

3.3 Do you believe that there is, on academic grounds, a need for the MLSC?

Yes ☐ If so, why?

No ☐ If not, why?

3.4 Do you believe that there is, for economic reasons, a need for the MLSC?

Yes ☐ If so, why?

No ☐ If not, why?
Section 4: Future Expansion and Development of the MLSC

Assuming that the MLSC does expand

4.1 How would you feel if the MLSC was relocated to an area elsewhere on campus?


4.2 How do you think that the MLSC would be perceived if it were relocated to an area elsewhere on campus?

a) By the students


b) By academic staff in departments other than mathematics, physics and engineering


4.3 Do you think that the MLSC should have a separate reception area?

Yes □ If so, why?    

No □ If not, why?  

Don’t know   


4.4 Do you think that there should be a café incorporated into the MLSC?

Yes □ If so, why?    

No □ If not, why?  

Unimportant   

- 393 -
4.5 Do you think that the MLSC should have individual work areas for private study?

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<tbody>
<tr>
<td>Yes</td>
<td></td>
<td>If so, why?</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>If not, why?</td>
</tr>
<tr>
<td>Unimportant</td>
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</table>

4.6 Do you think that the MLSC should have its own toilets?

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<tbody>
<tr>
<td>Yes</td>
<td></td>
<td>If so, why?</td>
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<tr>
<td>No</td>
<td></td>
<td>If not, why?</td>
</tr>
<tr>
<td>Unimportant</td>
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</tbody>
</table>

4.7 Do you think that the MLSC should have a separate room in which students with Special Needs can work and obtain support?

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<tbody>
<tr>
<td>Yes</td>
<td></td>
<td>If so, why?</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>If not, why?</td>
</tr>
<tr>
<td>Insufficient understanding of Special Needs to answer this question</td>
<td></td>
<td></td>
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</table>

4.8 If a separate room for students with Special Needs is introduced, should this room have specialist mathematics support staff, i.e. staff with an understanding of the difficulties experienced by dyslexic students?

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<tbody>
<tr>
<td>Yes</td>
<td></td>
<td>If so, why?</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>If not, why?</td>
</tr>
<tr>
<td>Insufficient understanding of Special Needs to answer this question</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 5: Suggestions

5.1 Please make suggestions regarding what you feel constitutes a good working environment, e.g., ideas relating to furnishings, decor, room layout, amenities etc.

Section 6: Working in the MLSC

ONLY TO BE COMPLETED BY STAFF WHO HAVE WORKED OR ARE WORKING IN THE MLSC ON A REGULAR TIMETABLED BASIS

The following questions deal with your personal experience in the MLSC and are to be answered to the best of your knowledge (to avoid ‘in my opinion’ being stated in every question)!

6.1 For what proportion of the time that you spend in the MLSC do you find it to be overcrowded (i.e., students waiting more than 15 minutes)?

- All
- Almost all
- More than half
- About half
- Less than half
- Almost none
- None
6.2 Do you feel equipped to deal with the range of questions that you are asked in the MLSC?

Yes □
No □

6.3 What proportion of students using the MLSC appear anxious about their difficulties with mathematics?

All □
Almost all □
More than half □
About half □
Less than half □
Almost none □
None □

6.4 What do you consider is the most frequent reason for students using the MLSC?

Approaching examinations □
Coursework deadlines □
Other, please specify □

6.5 What proportion of the time that students spend in the MLSC do you consider is due to approaching examinations or coursework deadlines?

All □
Almost all □
More than half □
About half □
Less than half □
Almost none □
None □
6.6 Are you able to determine if any of the students you encounter in the MLSC are regular attendees?

Yes ☐
No ☐

6.7 **If you have answered ‘yes’ to the above question,** have these regularly attending students made significant progress?

Yes ☐
No ☐
Don’t know ☐

6.8 Do you feel that students prefer to see the same lecturer at each visit?

Yes ☐
No ☐
Don’t know ☐

6.9 Regarding students in the MLSC who were **unable** to understand your initial explanation, for what proportion of them was this lack of understanding due to their mathematical background being weaker than was immediately apparent?

All ☐
Almost all ☐
More than half ☐
About half ☐
Less than half ☐
Almost none ☐
None ☐
6.10 What proportion of students in the MLSC were able to understand your initial explanation?

All ☐
Almost all ☐
More than half ☐
About half ☐
Less than half ☐
Almost none ☐
None ☐

6.11 How should staff in the MLSC explain a topic to the students?

By following the module lecturer’s notes (if available) ☐
By using an alternative method(s) ☐ If so, why

6.12 Who do you feel should be allowed to use the MLSC?


6.13 What proportion of students appear to be embarrassed or inhibited about using the MLSC?

All ☐
Almost all ☐
More than half ☐
About half ☐
Less than half ☐
Almost none ☐
None ☐
6.14 How should staff in the MLSC deliver mathematics to the students?

Please tick all options you consider to be applicable

- Chalk and board
- White board and marker pen
- Overhead projector
- PowerPoint
- Pen and paper
- Computer assisted learning
- Other, please specify

6.15 Do you feel that the MLSC provides a comfortable environment for the students who attend it?

Yes [ ]
No [ ]

6.16 Do you feel that the one-to-one support offered in the MLSC should be advertised as specific to any of the following topics?

Please tick all applicable options

- Basic Mathematics
- Linear Algebra
- Calculus
- Statistics
- Other, (please specify)

6.17 What do you do if a student tells you that the question is coursework and then asks for some assistance?

- Answer the question [ ]
- Give some applicable help [ ]
- Direct the student to a relevant section of their notes or a textbook [ ]
- Refuse to help [ ]

6.18 Are you made aware of coursework questions for all the mathematics modules?

Yes [ ]
No [ ]
6.19 Have there been occasions when you realized that students had tricked or tried to trick you into answering a coursework question?

Yes [ ]
No [ ]

If you have answered ‘yes’ to the above question

How often has this occurred?

Frequently [ ]
Occasionally [ ]

6.20 What do you do if you find that you have been tricked into answering a coursework question?

Nothing [ ]
Report the student to his/her department [ ]
Other, please specify

6.21 What do you do if you realize that a student is trying to ‘trick’ you into answering a coursework question?

Answer the question [ ]
Give some applicable help [ ]
Direct the student to a relevant section of their notes or a textbook [ ]
Refuse to help [ ]

6.23 How do you deal with a question that is outside your realm of expertise?

Persevere (if MLSC is not too busy) [ ]
Refer to another member of staff [ ]
Say that you are unable to help [ ]
Other, please specify

- 400 -
6.24 Disregarding financial aspects and taking only academic considerations into account, do you feel that your involvement in the MLSC, i.e. aiding students to increase their mathematical understanding, is worthwhile?

Yes ☐
No ☐
Don’t know ☐

6.25 What effect has your being a professional mathematician had on your understanding of students’ problems in the MLSC?

Enhanced ☐
No effect ☐
Hindered ☐

6.26 If the government objective that 50% of the population aged between 18 and 30 should enter HE by 2010 is achieved (currently 43% nationwide, however, there are significant regional variations and the percentage in the East Midlands is less than this), what do you think will be the effect on the workload in the MLSC, given that current levels of staffing are maintained?

Unchanged ☐
Manageable ☐
Unbearable ☐

6.27 Why do you want to be involved with the MLSC?

Because it may become a Centre for Excellence ☐
I find it rewarding ☐
It fills my teaching workload ☐
I don’t ☐
Other ☐
6.28 If a separate room were to be incorporated into the MLSC for students with Special Needs, would you like to assist these students?

Yes ☐
No ☐

6.29 Statistics collected in the MLSC show that an increasing number of students visit it. Some students use the MLSC to work in and others for assistance. If you have worked in the MLSC for 3 years or more (not necessarily consecutively), does there appear to be an increase in the number of students requiring help?

Yes ☐
No ☐

6.30 If you have worked in the MLSC for 3 years or more (not necessarily consecutively), does there appear to be an increase in the number of students attending from departments other than mathematics?

Yes ☐
No ☐

Any additional comments or suggestions would be welcome.

We hope that completing this census has provoked you into thinking about ways in which the MLSC could develop.

If other ideas occur to you, please e-mail your suggestions to: G.Perkin@lboro.ac.uk

Thank you for spending valuable time completing this census; your contribution is greatly appreciated!
F.6 The Student Questionnaire

QUESTIONNAIRE
ON
THE MATHEMATICS LEARNING SUPPORT CENTRE

For Students Using the Mathematics Learning Support Centre
at Loughborough University

INDIVIDUAL NAMES WILL NOT BE RELEASED

Please hand in your completed form at the reception desk

The names of all students who complete the questionnaire by 2\textsuperscript{nd} June 2005 will be entered into a prize draw; 1\textsuperscript{st} prize \£20.00, 2\textsuperscript{nd} prize \£10.00, 3\textsuperscript{rd} prize \£5.00, which will take place on Friday 3\textsuperscript{rd} June 2005 at 1.00pm.

| Section 1: Personal Data | Section 2: General Questions | Section 3: Reasons for having the MLSC | Section 4: Expansion & Development of The Mathematics Learning Support Centre (MLSC) | Section 5: Suggestions | Section 6: Support in the MLSC |

Please fill in details/comments or tick the boxes as appropriate

Section 1: Personal Details

1.1 Name

1.2 Age at commencement of programme

- 403 -
1.3 Which year of study are you currently registered on?

Foundation
1st year
2nd year
3rd year
4th year
5th year

1.4 Which university department are you registered in?

[Blank]

1.5 How do your pre-university results compare with your university examination/coursework results?

Your mathematics A Level Grades

Current degree expectation

or

Other mathematical background, please specify

Current degree expectation

Section 2: General Questions

2.1 Did your university course start at a higher level than your mathematical background had prepared you for?

Yes

No
2.2 What are your difficulties in mathematics generally related to?

- A specific question
- A whole lecture
- Your pre-university mathematical background
- Other, please specify

2.3 What are the main areas in which you experience mathematical difficulties?

Please tick all options you consider to be applicable

- Basic manipulation
- Other, please specify
- Linear algebra
- Calculus
- Statistics

2.4 Do you have any suggestions regarding ways in which students might be helped with their mathematics (other than the MLSC)?

2.5 Do you feel that the MLSC is well located for its purpose?

- Yes
- No If not, where do you think that it should be located?

2.6 Are you aware that the MLSC runs a series of lunchtime support sessions?

- Yes
- No
2.7 On entering the MLSC, what is your impression of it?

- Warm and friendly
- Neutral
- Daunting
- Other, please specify

2.8 How did you become aware of the existence of the MLSC?

Please tick all applicable options

- Open Day
- Commencement of study / registration
- Campus advertisements
- Word of mouth / peer group
- Personal Tutor
- Lecturer
- University web page

2.9 Are you dyslexic or awaiting results of testing for dyslexia?

- Yes
- No

If you have answered ‘yes’ to the previous question

2.10 Were you diagnosed as dyslexic prior to commencing your studies at Loughborough University?

- Yes
- No
2.11 If you have been diagnosed as dyslexic whilst at Loughborough University or are currently awaiting testing for dyslexia, what was the reason for you suspecting that you might be dyslexic?

Suggestion at school/college that you undergo testing for dyslexia
Suggestion by a member of the MLSC
Suggestion by your personal tutor
Suggestion by a lecturer
Suggestion by a friend
Seeing literature displayed in the MLSC

Section 3: Reasons For Having a Mathematics Learning Support Centre

3.1 Do you believe that the university should provide mathematics support, over and above that provided by lectures and tutorials?

Yes ☐ If so, why

No ☐ If not, why

3.2 What do you believe is the reason for students seeking help with mathematics?

Please tick all options you consider to be applicable

Increased academic level of courses ☐
Decrease in knowledge of incoming students ☐
Increase in the number of dyslexic students ☐
Lowered academic recruitment level ☐
Students today demand / expect more support ☐
Other, please specify
3.3 Do you believe that there is, on academic grounds, a need for the MLSC?

Yes [ ] If so, why?

No [ ] If not, why?

3.4 Do you believe that there is, for economic reasons, a need for the MLSC?

Yes [ ] If so, why?

No [ ] If not, why?

Section 4: Future Expansion and Development of the MLSC

Assuming that the MLSC does expand

4.1 How would you feel if the MLSC was relocated to an area elsewhere on campus?

4.2 What would your perception of the MLSC be if it were relocated to an area elsewhere on campus?
4.3 Do you think that the MLSC should have a separate reception area?

Yes  [ ]  If so, why?  

No  [ ]  If not, why?  

Don’t know  [ ]

4.4 Do you think that there should be a café incorporated into the MLSC?

Yes  [ ]  If so, why?  

No  [ ]  If not, why?  

Unimportant  [ ]

4.5 Do you think that the MLSC should have individual work areas for private study?

Yes  [ ]  If so, why?  

No  [ ]  If not, why?  

Unimportant  [ ]
4.6 Do you think that the MLSC should have its own toilets?

Yes  □  If so, why? □

No  □  If not, why? □

Unimportant  □

4.7 Do you think that the MLSC should have a separate room in which students with Special Needs can work and obtain support?

Yes  □  If so, why? □

No  □  If not, why? □

Insufficient understanding of Special Needs to answer this question  □

4.8 If a separate room for students with Special Needs is introduced, should this room have specialist mathematics support staff, i.e., staff with an understanding of the difficulties experienced by dyslexic students?

If so, why?  □

No  □  If not, why? □

Insufficient understanding of Special Needs to answer this question  □
Section 5: Suggestions

5.1 Please make suggestions regarding what you feel constitutes a good working environment, e.g., ideas relating to furnishings, decor, room layout, amenities etc.

Section 6: Support in the MLSC

6.1 For what proportion of the time that you spend in the MLSC do you find it to be overcrowded (i.e., a wait of more than 15 minutes)

- All
- Almost all
- More than half
- About half
- Less than half
- Almost none
- None
6.2 Do you feel that the MLSC is able to assist with your mathematical needs?
Yes ☐
No ☐

6.3 Are you anxious about your difficulties with mathematics?
Yes ☐
No ☐

6.4 What is your most frequent reason for using the MLSC?
Approaching exams ☐
Coursework deadlines ☐
Other, please specify ☐

6.5 What proportion of your time spent in the MLSC is due to approaching examinations or coursework deadlines?
All ☐
Almost all ☐
More than half ☐
About half ☐
Less than half ☐
Almost none ☐
None ☐

6.6 Do you visit the MLSC on a regular basis (i.e., at least once per week)?
Yes ☐
No ☐

If you have answered ‘yes’ to the previous question
How many hours per week do you spend in the MLSC? 

6.7 Do you believe that attending the MLSC has improved your progress?
Yes ☐ 
No ☐ 
Don’t know ☐ 

6.8 Do you, where possible, time your visits to the MLSC to enable you to see the same lecturer(s)?
Yes ☐ 
No ☐ 

6.9 If there have been occasions when you were unable to understand the initial explanation given by a lecturer, how often is this due to the lecturer assuming that your underlying mathematical knowledge is greater than it actually is?
All ☐ 
Almost all ☐ 
More than half ☐ 
About half ☐ 
Less than half ☐ 
Almost none ☐ 
None ☐ 

6.10 How often have you been able to understand the initial explanation given by a lecturer in the MLSC?
All ☐ 
Almost all ☐ 
More than half ☐ 
About half ☐ 
Less than half ☐ 
Almost none ☐ 
None ☐ 

- 413 -
6.11 How do you feel that staff in the MLSC should explain a topic to you?

By following your lecture notes (if you have them with you) □

By using an alternative method(s) □ If so, why □ □ □ □ □ □ □ □

6.12 Who do you feel should be allowed to use the MLSC?

□ □ □ □ □ □ □ □

6.13 Did you initially feel embarrassed or inhibited about visiting the MLSC?

Yes □
No □

If you have answered ‘yes’ to the above question, did this feeling persist after your first visit to the MLSC?

Yes □
No □

6.14 How should staff in the MLSC deliver mathematics?

Please tick all options you consider to be applicable

Chalk and board □
White board and marker pen □
Overhead projector □
PowerPoint □
Pen and paper □
Computer assisted learning □

Other, please specify □ □ □ □ □ □ □ □
6.15 Do you feel that the MLSC provides a comfortable environment in which to work and seek assistance?

Yes ☐
No ☐

6.16 Do you feel that the one-to-one support offered in the MLSC should be advertised as specific to any of the following topics?

Please tick all applicable options

| Basic Mathematics ☐ | Other (please specify) |
| Linear Algebra ☐ | |
| Calculus ☐ | |
| Statistics ☐ | |

6.17 What has the response been from lecturers if you have explained that the question is coursework?

They've answered the question ☐
Given some applicable help ☐
Directed you to a relevant section of your notes or a text book ☐
Refused to help ☐

6.18 What do you most frequently use the MLSC for?

Computer on-line help ☐
Handouts ☐
A place to work ☐
One-to-one support ☐
Mathematics textbooks ☐

6.19 Do you feel that the opening hours of the MLSC enable you to avail yourself of the service as frequently as you would like?

Yes ☐
No ☐
6.20 What proportion of the staff that you have encountered in the MLSC are friendly and helpful?

- All
- Almost all
- More than half
- About half
- Less than half
- Almost none
- None

6.21 Have you used any of the handouts in the MLSC?

- Yes
- No

**If you have answered ‘yes’ to the previous question**

6.22 How would you describe the information and examples, which they contain?

- Excellent
- Good
- Adequate
- Insufficient

6.23 Have you encountered any topics for which there was not a handout but you feel that one would have been helpful?

- Yes
- No

If so, what?
6.24 If you are dyslexic or awaiting testing for dyslexia, does the available support in the MLSC meet your needs?

Yes  □

No   □

If you have answered ‘no’ to the previous question

6.25 What additional support would you like to have?

Thank you for spending valuable time completing this questionnaire; your contribution is greatly appreciated!
APPENDIX G: Historical Perspective of Education in the UK

G.1 Elementary Education in the 18th Century

During the 18th century the majority of the population in the UK had little or no opportunity to experience the benefits of education; social class largely determined the amount of education that an individual might expect to receive. Educating the bulk of the population, did not, in the 18th century, have any economic value. Aldrich (1996:10) explains that children born to poor parents were expected to work from an early age and understood the need to contribute to the family income.

Prior to the 19th century, the state had little interest in the education of its subjects. It was happy to leave the business of educating the poor to the church, to benevolent societies and to individuals. The sentiment of this period is described by Barnard (1961:52) as:

The educational ideal of the time was the training of the poor to an honest and industrious poverty which knew its place and was duly appreciative of any favours received.

There was, however, an increase in literacy (measured by the ability to sign one’s own name on marriage registers) during the first two-thirds of the 18th century. It is estimated that between 1700 and 1775 male literacy in England and Wales increased from just less than 50% to 56%. During this period the acquiring of literacy was aided by a notable expansion of endowed schools prompted by the work of The Society for the Promotion of Christian Knowledge. Between 1710 and 1730, a total of 91 new endowed schools were built in the counties of Cheshire, Derbyshire and Lancashire. However, even with this increase in basic literacy and regardless of social status, there existed a wide disparity between males and females, with many more males than females acquiring literacy (Sanderson, 1991:9-13). Whilst there had been an increase in literacy, it is estimated that over 1.5 million poor children in England were not receiving any elementary education (Evans, 1975:15-17).
Towards the end of the 18th century the situation deteriorated. At this time there was rapid population growth and with the start of the Industrial Revolution came the employment of children as young as nine years of age, whereas previously, in rural areas undertaking, for example, farm work, they would not have been employed until they were around 12 years of age. The Sunday School movement started by Robert Raikes during the 1780's in Gloucester did, however, provide some schooling for children on the one day per week that they were not working (Sanderson, 1991:13).

Other forms of schooling were available to the working classes who wanted their children to have some education and could afford to pay for it. Barnard (1961:2-4) describes two types of elementary schooling that were available in England, the ‘dame school’, which was usually run by an elderly woman and the ‘common day school’ (sometimes referred to as a private day school) whose master was often physically handicapped or had failed at other types of employment. Both these schools offered only a rudimentary education for those who could afford the fees of a few pennies per week.

Effectively, elementary education for the majority of the UK population in the 18th century was irregular in its provision, of short duration and of poor quality. It was not until the 19th century that concern regarding education started to grow, eventually leading to state funding and the passing of significant legislation in 1870 that would place elementary education and education in general on a slow but steady path of progression.

G.2 Elementary Education in 19th Century England

It was not only in the 18th century that social class determined the type of education that an individual might expect to receive; Aldrich (1996:21) writes:

Throughout the nineteenth and twentieth centuries many of those who presided over state education in England identified it essentially as education for the poor, for those who, unlike themselves, could not or would not pay for the schooling of their own children.
It was the evidence of an official investigation, (the report of the parliamentary Select Committee on the Education of the Lower Orders of Society, 1818), which resulted in Lord Brougham describing England at this time as being the worst educated country in Europe. The investigation revealed that three-quarters of the child population were not receiving any education whatsoever (Evans, 1975:15). Sanderson (1991:26), acknowledging Sandberg, points out that in 1850 education in England was of ‘second rank’ even though at this time England was the richest and most industrially advanced country in the world.

Figures from the censes for England and Wales show that in 1801 the population was approximately nine million by 1851 it had grown to 18 million. This population increase was most noticeable in areas of commercial and industrial activity and by 1851 this rapid increase had resulted in approximately one quarter of the population being under ten years of age (Aldrich, 1982:15-16). Many children had formerly found employment but once the Factory Acts began to take effect there was a relative decline in employment opportunities for children and an inadequate number of places in schools (Evans, 1975:1-2). There was, however, an expansion of the Sunday School movement and Sanderson (1991:13), quoting Laqueur’s calculations, reports that by 1851 three-quarters of working class children aged between five and 15 were attending these schools.

Evans cites the shortage of both money and teachers as being the two primary problems, in the early 19th century, which confronted any attempt to expand elementary education. A solution to this problem was the introduction of the monitorial system, which was devised independently by the Anglican clergyman Andrew Bell and the Quaker Joseph Lancaster (Evans, 1975:17). This system was found particularly useful for the rapid and mass education of children. Effectively, more senior children educated the younger children. The master only had to educate the monitors who then passed on the instruction they had received. By using this system large numbers of pupils could receive basic education at little cost. The monitorial system soon became more widespread and was to remain popular for approximately 30 years. The education that these schools provided was, however, divided on religious grounds with the Anglicans adopting Bell’s version of the system and the Nonconformists adopting Lancaster’s version. Two societies, with strong denominational interest, were set up to promote
these differing styles of monitorial school and were to become the most powerful educational agencies of this time (Aldrich, 1982:73-75).

The growing interest in education in the early 19th century was fuelled by a series of attempts in the 1820’s to obtain state intervention in education. In 1833, John Roebuck, a radical Member of Parliament, proposed extensive plans for the compulsory education of those aged between six and 12 and the setting up of four different types of school. It is not surprising that he failed, given the scale and cost of his proposals. Nevertheless, 1833 was a significant year as it heralded the first state intervention in education; popular representation stimulated parliamentary interest and the Government voted the sum of £20,000 for the erection of school buildings. This grant was renewed on an annual basis and by 1859 it was worth £836,920. During the first five years of its existence this grant was issued to, and managed by, the two societies established to further the monitorial system (Barnard, 1961:67-70).

Once the state had intervened in the provision of elementary education, the process of improvement and reform became relatively rapid. Central to this progress, in the middle of the nineteenth century, was the work of Sir James Kay-Shuttleworth. Evans (1975:20-22) writes of his varied and considerable achievements, which included the development of administrative systems and agencies to dispense funds from government, the establishment of a schools’ inspectorate and the launch of the pupil-teacher system. The pupil-teacher system allowed for the systematic training of teachers and remained in place until the end of the 19th century.

The 1870 Elementary Education Act (Forster Act) was the first effective piece of legislation to deal with education. It aimed to make available elementary education in England and Wales for all children aged from five to 13, “This critical landmark in our educational history formed the watershed between mere State assistance for and direct State provision of elementary education”. However, this education, covering the three R’s – reading, writing and arithmetic, was neither compulsory nor free. The countries were divided into school districts and School Boards were set up in areas where the existing provision of education was found to be unsatisfactory. Schools set up under these arrangements became known as Board Schools, which were funded from central
government, by a fee of up to 9d per week from parents and by rate aid (Evans, 1975:28-37).

There were a number of factors, which helped to bring about the drafting and passing of this Act. Successive Factory Acts were helping to control the employment of young children. The 1867 Factory Act debarred 200,000 children from paid employment, which resulted in thousands of children on the streets in densely populated areas. There was still a continuing population expansion and the then current system of elementary education was inadequate (Evans, 1975:28-31). However, it was Britain’s failure to secure many prizes at the 1867 International Exposition in Paris that raised awareness of the link between education and industry. A series of investigations revealed the inadequacy of secondary and technical education in Britain when compared to that taking place in Prussia and America. An illiterate workforce was becoming to be seen as a barrier to industrial growth (Sanderson, 1999:14-17).

The long-term growth in education since the 1830’s has been matched by an increase in expenditure. In 1833, public expenditure on education in the UK amounted to 0.01% of the gross domestic product (GDP) and had risen to 4.31% in 1999. Whilst there had been an increase in the student population, this does not explain the growth in the actual expenditure per student; at 1990 prices, expenditure per student was approximately 30 times greater than in the 1850’s (Carpentier, 2003:4-6).

As a result of the 1880 Education Act (Mundella Act), attendance at school became compulsory for children in England and Wales between the ages of five and ten, This Act, which was reinforced by School Attendance Officers, resulted in school attendance rising from 1.2 million to 4.7 million between 1860 and 1900. Although, at this time, education was still not necessarily free, it was the 1891 Education Act that was to make elementary education almost free. As a consequence of legislation and financial intervention by the state, elementary education, in the latter part of the 19th century, had been radically transformed (Sanderson, 1999:4-5).
By the 19th century there was a significant number of secondary education places available for those who could afford them, or for those who were fortunate enough to gain a scholarship. In addition to the public schools (with their own feeder schools known as preparatory schools) whose purpose was the education of gentlemen and attendance at which confirmed professional, middle, and upper class status there was a variety of other schools offering secondary education. The Schools Inquiry Commission, chaired by Lord Taunton (1864-8), identified three categories of these aforementioned other schools; the endowed (elementary and grammar) schools, which were not maintained by public money, the proprietary schools, which were under private management and the private schools, which were profit-making establishments. These three categories provided education up to and beyond 14 years of age, dependent upon the type of school that the pupil was attending. The Commissioners found that the endowed schools were failing to provide “a good education for the lower section of the middle classes and respectable artisans”. The Taunton Commission also reported: “We cannot but consider that it is a matter of national interest, that boys of real ability, in whatever rank of life they may be found, should receive every aid and encouragement that can rightly be given to enable them to rise to a position suitable to their talents” (Aldrich, 1982:104-108).

The Taunton Commissioners effectively recommended a national system of secondary education, which, where possible, should be extended to make provision for girls as well as boys. Had its recommendations been implemented, it would have made available a secondary education to complement the elementary education provided by the 1870 Education Act.

The use of examinations to test the performance of pupils, and league tables for measuring the performance of individual schools is not a 20th century introduction. Aldrich (1996:45-49) explains that the use of examinations to test the performance of pupils in the 19th century was commonplace. Elementary schools, for example, were dependent on funding through the 1862 Revised Code, which scaled its awards to the overall success or otherwise of the school. Not surprisingly, for the elementary or secondary school, pupils’ success in examinations had an impact on public perception.
The College of Preceptors (founded and controlled by teachers), the Royal Society of Arts and the Universities of Oxford and Cambridge were all setting examinations for school children from the middle of the 19th century, which, if passed, improved a pupil’s employment prospects and quite quickly league tables, which ranked schools by their examination success, began to appear in the educational press.

What had been started in the 19th century was a process of educational reform whereby the state began to take responsibility for the education of the majority of its citizens.

**G.4 Elementary Education in 20th Century England**

Statistics show that by 1901 three-quarters of the English population lived in towns and cities and thus education moved from being widely dispersed and essentially a rural undertaking to become an urbanised and centralised process. In 1911, the population of England and Wales had doubled from its 1851 figure to 36 million (Aldrich, 1982:15-18). The number of school places had also risen and the dual system of non-denominational School Boards and the church schools were, by 1901, providing over 4.5 million elementary school places where in 1870 there had been less than 1.25 million places (Evans, 1975:34). Literacy, as defined earlier (the ability to sign one’s own name) had also risen from 80% in 1870 to nearly 100% by 1913 (Sanderson, 1999:3).

The 1902 Education Act (Balfour Act) abolished School Boards, gave responsibility for elementary education to LEA’s and established a system of secondary education, which was to be provided by the LEA’s. However, in England and Wales it was the 1918 Education Act (Fisher Act) that finally abolished all fees for elementary schools and raised the school leaving age to 14 (Mackinnon, Statham & Hales, 1996:48-49).

**G.5 Secondary Education in 20th Century England**

The 1902 Education Act provided the impetus for secondary education and foresaw the possibility of developing an integrated system of education whereby a pupil could
progress from elementary to secondary schooling and beyond it to Further Education (FE) and HE (Evans, 1975:59-72).

This Act, which applied to England and Wales, also consolidated and expanded the grammar schools, which from 1907 were required to set aside one-quarter of their places for scholarship winners. The possibility of obtaining a scholarship place through the ‘eleven plus’ examination soon allowed those who had worked through the elementary school system the chance of a secondary education (Sanderson, 1999:10-11). This is referred to by Evans (1975:69-70) as:

... the ultimate rejection of the nineteenth-century concept of secondary education as the prerogative of the middle and upper classes.

Secondary education was available to those who could afford the fees and to those who gained a scholarship; for others the prospect of attending a secondary school was not a possibility. The educational system was still essentially a two-tier system with elementary schooling available up to 14 years of age and secondary education available, predominantly through the grammar schools, up to the age of 18.

New examinations were introduced in 1917 to help reduce the number of secondary school examinations and examining boards. These nationally-recognised examinations were School Certificate and Higher School Certificate. The School Certificate, which required five subjects to be passed, was taken by pupils aged 16 after five years of study and Higher School Certificate after a further two years of sixth form study. Effectively, these examinations started to standardise the secondary curriculum and confirm its academic nature (Aldrich, 1996:51).

Not surprisingly, the progress to secondary education for all was preceded by a number of government reports, which paved the way for its introduction. Notably, the 1926 report on The Education of the Adolescent (Hadow Report), the 1938 Report on Secondary Education (Spens Report) and the 1941 Report on Curriculum and Examinations in Secondary Schools (Norwood Report), all of which provided the basic strategies for a secondary education for all. At the time of the Hadow Report, less than 10% of all adolescents were attending secondary grammar schools (Evans, 1975:82-86).
The Hadow Report outlined the basic structure of a two-tier system divided into primary and secondary education with all pupils passing, at the age of 11, to secondary schools (Aldrich, 1996:13). The report recommended that from September 1932 the school leaving age be raised to 15 but this was not implemented until 1947. The system would remain selective with selection taking place at 11 years of age, the ablest pupils continuing their education at secondary grammar schools and the remainder going to secondary modern schools until the age of 15. It was suggested that the first two years in each school would provide a sound basic education, then as a result of ability, determined by the selection process, the grammar school pupils would continue with an academic education and the secondary modern pupils would receive a more practical education. The intention was that the secondary modern school would be seen as different to the secondary grammar school but not inferior to it and there would be parity in funding and esteem to both types of school. The report was accepted and a gradual reorganisation began to take place. Whilst equality of status may have been the intention at the time, in practice the grammar schools were more generously funded than the secondary modern schools whereby the secondary modern schools lost the intended parity and esteem (Evans, 1975:82-84).

The Spens Report, which consolidated the work of Hadow, also made some significant recommendations to the existing policy, in particular: that all fees for State secondary education should be abolished thereby making it only possible to enter a grammar school by selection (subsequently included in the 1944 Education Act), that some of the technical schools should be converted into technical high schools, later to be named secondary technical schools, and that general administrative arrangements be updated (Evans, 1975:84-85).

Norwood in his report of 1943 argued that there were three types of children. Some “were interested in learning for its own sake” and would be channelled through the grammar school system regardless of their social background. For those pupils with “an uncanny insight into the intricacies of mechanism” they would find themselves in the secondary technical schools, yet in reality not many of these schools were available. For the majority who “deal more easily with concrete things rather than ideas” they would be educated in the secondary modern school. Thus the foundations were laid for the
tripartite system of secondary education, where access to each school would be controlled by selection at 11 years of age (Aldrich, 1996:13-15).

Even with this scholarship system, during the inter-war years, secondary schooling was not really a viable option for a large sector of the working-class population. They remained in elementary schools that provided education up to the age of 14 only. Many children from working class backgrounds were either not entered for the scholarship examination or were put off from entering it due to concerns related to the associated costs and possible alienation from their families and friends (Aldrich, 1996:14).

The 1944 Education Act (Butler Act) replaced all other previous educational legislation, made groundbreaking advances for the provision of education in England and Wales and covered many areas of education. The main points are that it provided a statutory basis for secondary education for all, abolished all fees and associated costs for state-funded secondary, technical and grammar schools, and places were to be obtained purely on academic ability. The school leaving age was to be raised first to 15 and then to 16 as soon as it became viable (however, this was not implemented until April 1947). It also replaced the Board of Education with a Ministry of Education. This Legislation was interpreted and acted upon by the LEA’s and the tripartite system of education came into existence although the Act itself did not specify any particular system. Reference in this Act was also made to FE, placing on LEA’s the need to secure adequate facilities for this, in addition to making provision for primary and secondary education (Evans, 1975:97-103).

In 1951, the GCE O Level and GCE A Level respectively, replaced the School Certificate and the Higher School Certificate. It was intended that pupils at secondary grammar schools would take these examinations. However, after 1952, secondary modern schools were allowed to enter pupils for external examinations and this resulted in some pupils at these schools spending an extra year at school and obtaining passes at GCE O Level. Only a minority of schools had the facilities to offer this option, nevertheless, this began to cast doubt on the accuracy of the eleven plus examination (Evans, 1975:111).
Inevitably the number of grammar school places available, for pupils undertaking the eleven-plus examination, varied throughout England, being between 10% and 40%, dependent upon the number of places available in a particular area. Another worry was that the eleven-plus examination was found to be inaccurate. An investigation in 1957 estimated that it was misplacing approximately 70,000 pupils each year (Evans, 1975:110-111).

The Crowther Report, published in 1959, investigated the education of 15-18 year olds in England. This report found that pupils at secondary modern schools were educationally disadvantaged and suggested that one-third of secondary modern pupils were capable of sitting an external examination at an academic level below that of GCE O Level. The introduction of the Certificate of Secondary Education (CSE) in 1965 is attributed partly to this recommendation (Evans, 1975:181-185).

The CSE examination was well received, and it soon followed that a CSE Grade 1 was defined as being equivalent to a GCE O Level pass (Evans, 1975:291). The GCE O Level catered for those pupils deemed, by the selection process, to be in the top 20% of academic ability and CSE for the next 40% of the cohort (Aldrich, 1996:51-59). However, it is pertinent to mention that failure to obtain a place at a grammar school generally denied a pupil the opportunity to be entered for the GCE O Level examinations. Taking into account both the GCE O Level and the CSE examinations, there were still approximately 40% of pupils leaving school without any qualifications whatsoever.

The Labour Party had openly supported the idea of comprehensive schooling since 1942 and during the 1950’s there was growing interest in the idea of comprehensive education, comprehensive schools would be non-selective and accept pupils regardless of their ability. In 1951 the Labour Party produced ‘A Policy for Secondary Education’ and came out strongly in favour of comprehensive education. There was mounting concern over the eleven-plus examination, which was seen to be divisive. Many working-class children who did gain a place at grammar school performed less well than middle class children and success seemed to be decided by social class and locale rather than by ability. By 1964 there were over 200 comprehensive schools, which catered for nearly 8% of the secondary school population (Evans, 1975:111-112).
In 1965 the Labour Government issued Circular 10/65 on ‘The Organisation of Secondary Education’. This Circular requested LEA’s to submit plans for the reorganisation of secondary education into comprehensive schooling. However, a change of government ensued and in 1970 the Conservative government withdrew Circular 10/65, replacing it with Circular 10/70, which allowed LEA’s the freedom to choose between selective or comprehensive education (Mackinnon, Statham & Hales, 1996:53-55). Nevertheless, Simon (1991:299) reports that between 1965 and 1977 comprehensive education grew from 8.5% of schools to 31%.

With each change of government that took place from the 1960’s to the 1980’s there was conflict and controversy regarding the implementation of comprehensive education. Mackinnon, Statham and Hales (1996:53-58) explain that the 1976 Education Act attempted to eliminate selection by ability but the 1979 Education Act then repealed this. The school leaving age was finally raised to 16 in 1972, almost 30 years after the 1944 Education Act had made this recommendation. Attempts have been made to restore selection at 11 years of age but they have, in most cases, been resisted. Nevertheless, there do still exist a small number of selective grammar schools, located mainly in Berkshire, Buckinghamshire, Kent and Lincolnshire, which rely on the eleven plus examination (http://www.elevenplusadvice.co.uk/11-Plus-Areas.aspx). By 1982, 89.3% of pupils in England were attending comprehensive schools, which were clearly the schools for the future (Simon, 1991:483).

Throughout the 1960’s and 1970’s criticism of the dual system of examinations, which were generally taken at age 16, was the subject of much public debate and received significant media coverage. With the recognition that the eleven-plus examination was incorrectly placing some pupils and with the growth in comprehensive education, pressure was mounting to create a single examination that a greater proportion of 16 year olds could take. Simon (1991:305-307, 455) explains that discussions began during the late 1960’s and a recommendation for a single examination was made in 1970. Many pupils at this time were being entered for both the GCE O Level examination and the CSE examination to minimise risk of failure. The perception then arose that the Mathematics GCE O Level was of higher status that the CSE (Cockcroft, 1982:132).
In 1978 the committee of the Waddell Report on School Examinations finally reported in favour of a single examination. The government of the day accepted the recommendation and in 1978 it was announced that a single examination system to be known as the GCSE would be introduced, replacing both the GCE O Level and the CSE. The GCSE syllabi were introduced in 1986 with the first examinations being taken in 1988 by pupils in England, Wales and Northern Ireland (Mackinnon, Statham & Hales, 1996:33).

The change from the parallel system of GCE O Level and CSE to a single GCSE examination, to be taken by almost all 16 year-olds, unavoidably had a significant impact on schools, teachers and, of course, the number of 16 year-olds leaving school with a qualification. Figures given by Patrick (1996:3) show that in 1976 only 60% of the population had the opportunity to sit GCE O Level or CSE examinations but by 1996 GCSE examinations were being taken by over 90% of 16-year olds.

The GCE O Level and GCE A Level syllabi had been complementary, allowing a relatively smooth transition between the two for those pupils who wished remain at school until they were 18. After the introduction of GCSE in the late 1980’s, it became apparent that, in some subjects, there was a widening gap between the finishing point of GCSE and the starting point of A Level courses with the difference between the two becoming difficult to bridge. In 1988, The Higginson Committee investigated GCE A Level syllabi and recommended a more uniform marking system, a reduction in the number of syllabi, a compulsory core common to the remaining syllabi and that pupils study a greater number of subjects (Higginson Committee, 1988). However, these recommendations were rejected by the then Secretary of State (Mackinnon, Statham & Hales, 1996:42). Since the 1990’s several major changes to GCE A Level syllabi have ensued. These changes have resulted in many complex and heated debates regarding content and also suggestions of grade dilution. It was the concerns regarding A Level standards due to an increasing number of higher grades being achieved, which prompted a government-initiated inquiry. In 2002 Tomlinson published his report ‘Inquiry into A Level Standards’ and expressed his belief that if, due to hard work and improved teaching, there is an increasing proportion of students obtaining this qualification it does not follow that there has been a lowering of standards (Tomlinson, 2002:4).
Other changes to the educational system were made in 1988. The Education Reform Act made provision for the introduction of a common curriculum for those pupils of compulsory school age in England and Wales. This common curriculum was named the National Curriculum with attainment targets being set for pupils at the ages of seven, 11, 14 and 16 (Mackinnon, Statham & Hales, 1996:159-162).

The suitability of GCSE Mathematics as a foundation for further study and the content and depth of coverage of topics in GCE A Level is of considerable concern and has prompted a number of large-scale Government funded investigations and reports.

G.6 Higher Education

“Higher education courses are generally above the standard of GCE A-levels or National Vocational Qualification (NVQ) Level 3, which are job-specific vocational qualifications. They include degree courses, postgraduate courses and Higher National Diplomas. Higher education takes place in universities and higher education colleges, and in some further education colleges”.

(www.hefce.ac.uk/glossary/glossary.htm).

The earliest universities in the UK were of mediaeval origin with Oxford and Cambridge being the first in England. They were involved with study in the areas of law, medicine and the Church. Although initially of importance, their influence declined during the 18th century. It was during the 19th century that they gained international repute as a more orderly and cohesive structure started to emerge (Brophy, 2000:3-4).

A chapter on HE is included in Aldrich (1982:126-162), where it is explained that the 19th century brought about expansion; in the late 1820’s University College, with no religious education, and Kings College were founded in London. These colleges, unlike Oxford and Cambridge, were taking students from a much wider social background provided that they could pay the fees and pass the requisite entrance examinations, and were offering a broader curriculum. From 1851 nascent universities, in the form of civic university colleges, began to appear in major cities. These were created by generous benefactors or by public subscription and were to become important centres in industrial
research. From 1900, after successive investigations, these civic colleges gradually gained university status. The universities, that had started life as civic colleges, were to become known as redbrick universities. It was the Victoria Building at Liverpool University, built from pressed red bricks that led to a professor at this university coining this phrase (http://www.liv.ac.uk/gradschool/lifeliv.htm). State scholarships were introduced in 1920, although these were restricted to candidates of outstanding calibre.

By 1914, England had ten universities and four university colleges (Evans, 1975:248). These institutions were educating 18,228 full time students whereas a century earlier there had been only 1,128 students in total at Oxford and Cambridge (Aldrich, 1982:152). Aided by the introduction of the City and Guilds examinations in the late 19th century, polytechnics were developing in parallel to the new universities and technical institutions were also opening, at first, principally in London and then throughout the UK (Evans, 1975:219-220).

During the first half of the 20th century there was a slow rate of expansion; however, there was a rationalisation of curricula and examinations with National Certificates at Ordinary and Higher levels being offered. Additionally, some technical institutions were approaching, in the courses that they offered, the level and quality of university degrees (Evans, 1975:221-223).

Although universities were obtaining most of their funding from other sources, by 1914 they were receiving, collectively, £150,000 from the Government. Immediately after the First World War this was raised to £1m. The establishment of the University Grants Council in 1919 made it possible for universities to retain their independence from the Government whilst still benefiting from the funding provided. This allowed, during the inter-war years, for a steady but modest expansion of university places and courses. The Second World War profoundly affected public perceptions and expectations, and changes that included social welfare provision, a National Health Service and equal educational opportunities were soon to follow (Evans, 1975:252-257). Like elementary education, it was only when the State started to take an interest in HE that significant growth and change began to occur. Government funding for universities was to become the key to their success and continued expansion.
The 1944 Education Act had provided secondary education for all and consequently an expansion of grammar school places. This in turn led to an increase in demand for university places. Simon (1991:597) details that in 1944 there were some 38,000 full time students in British Universities and by 1964 this had risen to 139,000 students (not including those in teacher training colleges). The 1945 report on Higher Technological Education in England and Wales chaired by Lord Eustace Percy stressed that more scientists and technologists were needed to sustain industry and commerce in an increasingly competitive international market. This report recommended the expansion of science in universities and the creation of colleges of advanced technology. The 1946 Barlow Report on Scientific Manpower recommended more university places especially for science students, which confirmed the main findings of the Percy Report (Evans, 1975:220-234).

Added to the concerns regarding the need for scientists and technologists, there was also a requirement for more teachers due to the increase in birth rate since the end of the Second World War. Pressure for change was mounting and a Special Committee under the chairmanship of Lord Robbins, was set up to review the pattern of fulltime HE in Great Britain and make recommendations for its development. The main recommendations of the report were that the number of places in HE should be progressively increased from the 1963 figure of 216,000 (which includes those in teacher training colleges) to 560,000 by 1981. This increase in university places was to be achieved by the foundation of six new universities, by the granting of university status to ten existing colleges of technology and by expanding existing universities. Teacher training should also undergo expansion and receive elevated status. Robbins had seen the potential for a unitary system of HE where all the institutions could be managed as a single entity. The establishment of the Council for the National Academic Awards also helped this process; in 1964 it gave non-university institutions of HE the opportunity to develop their own degree work. However, also in 1964, the Labour Government announced a policy of separate administration within the HE sector for colleges and polytechnics; this gave rise to a binary system comprised of universities and non-university institutions (Evans, 1975:190-195).

Initially there was an increase in the number of students arriving at university to study applied science but this was soon followed by a decline. The universities of technology
were not attracting sufficient students and the term ‘technology’ began to be removed from their titles. The 1968 Dainton report on the flow of candidates in science and technology into HE identified that, whilst there had been an increase in the proportion of students taking GCE A Level mathematics up to 1960, this was followed by a decline as more pupils chose to study arts and social science subjects (Sanderson, 1999:96).

The polytechnics remained under the auspices of LEA’s until the 1988 Education Reform Act for England and Wales gave them autonomy; later, as a result of the 1992 Further and Higher Education Act, they gained university status (Holt, Andrews & Boyd et. al., 2002:244). With a growing number of students now successfully taking GCE A Level, and through government intervention, it followed that a greater number of students wished to enter university. To accommodate these students, universities have grown not only in number but also diversity, offering a widening range of undergraduate courses.

During the 20th century, the scene had been set to transform what had been an elitist system of education into one of mass education, where the majority could at least see that there was opportunity to enter HE even if they decided not to participate in it (Jary & Parker, 1998:3-5).

G.7 Mathematics Education Since 1986

Significant changes to the education system commenced in 1986 with the introduction of the GCSE, the first examinations being taken in 1988. Subsequently, changes were made to GCE A Level

G.7.1 GCSE Mathematics

The content of GCSE Mathematics syllabi has encountered criticism; this is principally because it does not cover all the topics that were included in GCE O Level. It has been suggested that the content of GCSE is approximately 60% of that which was formerly contained in GCE O Level (Mustoe, 1992:100; James, 1995:79). Additionally, the
subject may be taken at foundation level, intermediate level or higher level, which presents difficulties for employers, colleges and universities, as it is not clear from the certificate awarded which level has been taken and there is a significant difference in the material covered at each level. Howson (1996:135) draws attention to the incongruity of pupils being differentiated at GCSE Level yet those that go on to take GCE A Level all sit the same examination.

G.7.1.1 Content

Two topics that were previously undertaken at GCE O Level but not covered in GCSE syllabi are calculus and geometrical construction. The LMS, IMA and RSS, in their report ‘Tackling the Mathematics Problem’ (1995:9) divulge that there has been a marked shift of emphasis to time-consuming activities including investigations, problem solving, data surveys etc., at the expense of ‘core’ techniques. That these topics now feature predominately in GCSE is confirmed by Smith (2004:85-86) who discloses that 25% of the content in GCSE Mathematics is related to data handling. This issue is now being addressed; the response to the Smith Report, DfES (2004:42), states that the QCA have been asked to review the statistics and data handling content of GCSE to determine what should be retained in mathematics syllabi and what should be delivered through other subjects.

That the GCSE contains an overall reduction in mathematical content when compared to that of GCE O Level is confirmed by Sutherland and Pozzi (1995:8) and by Savage, Kitchen and Sutherland et. al., (2000:2), who, in the report ‘Measuring the Mathematics Problem’ produced by Hawkes and Savage write:

The GCE examination was replaced by GCSE which, for Mathematics, brought a decline in students concept of proof and in their technical fluency and understanding of algebra.

Smith (2004:7) expresses concern that the top 10% of mathematically able students are insufficiently stretched and motivated, and recommends that “attention be given to making special provision in mathematics for those more able pupils, both at GCSE and
The government in its initial response to the Smith report, DfES (2004:12), made the comment that mathematics curricula will be stretched for the most able. However, it is certainly not clear from this initial response how, in a classroom setting of pupils with mixed ability, this will be attained.

The LMS, IMA and RSS (1995:12-13) also raise the question, “Are current standards in mathematics at GCSE (Grades A-C) in any way comparable to those associated with GCE O-level and CSE (Grade 1)?” They emphasise that the mathematical knowledge that is required to obtain an A* on GCSE papers does not correspond to that which was required to obtain a good grade on GCE additional mathematics papers, which were previously taken, in addition to GCE O Level, by students with high mathematical ability. There is also a lack of emphasis placed on some areas such as arithmetic, fractions, ratios, algebraic techniques and the basic geometry of triangles, lines and circles. Moreover, it is these topics that are vital for further study in mathematics, science and engineering, which suggests that insufficient attention has been paid to the effectiveness of the curriculum for those students with the potential for further study.

Despite the grievances and contentious issues that have arisen, Smith (2004:82), whilst acknowledging serious concerns raised by respondents to the inquiry, expresses the opinion that:

> Compared with the previous O-level/CSE structure, GCSE mathematics has been beneficial to many more students and has provided them with an adequate background for further study in the subject.

If this is indeed the case, it is impossible to comprehend why difficulties with mathematics are now widespread across the HE sector in numerate disciplines.

**G.7.1.2 The 3-tier System**

Initially the grades awarded at GCSE were A-G, with A being the highest possible level of attainment. To distinguish exceptional performance, the A* grade was introduced in 1994. “From 1998, most major entry subjects, with the exception of mathematics, have
been examined through a Higher Tier covering grades A*-D and a Foundation Tier covering grades C–G. Mathematics is the only subject to have retained more than 2 tiers”. There are also a few subjects with only one tier. The reason for the 3-tier system was to allow coverage of a range of GCSE grades thus enabling candidates to demonstrate positive achievement by attempting questions that matched their ability within a specific tier. There is an overlap of grades between each tier and pupils may only sit a subject in one tier in any single examination period. The grades that may be achieved within each tier have undergone changes since the introduction of GCSE and are currently available as follows:

- Higher Tier: A*, A, B & C
- Intermediate Tier: B, C, D & E
- Foundation Tier: D, E, F & G

(Smith, 2004:57-58).

Smith (2004:83) also refers to the tactical behaviour of schools and pupils; it is perceived to be easier to obtain a grade B from the Intermediate tier, with its reduced algebra and geometry content, than from the Higher Tier. This, it is suggested, is influencing the number of candidates sitting each tier. Statistics show that when Grade B was introduced, as a possible outcome on the Intermediate Tier, entries for the Higher Tier fell from nearly 30% to approximately 15% of the candidate cohort; since then, the percentage sitting each tier has remained relatively stable. The response to the Smith report, DfES (2004:11) confirms that action will be taken to:

...address immediately concerns that the current structure of the three-tier GCSE may be discouraging, or in some cases preventing, young people from continuing their study of mathematics post-16.

Smith (2004:83) also draws attention to the preparedness of students, who have undertaken the intermediate tier, for the material encountered in mathematics at Advanced Subsidiary Level (AS) and A2 Level (previously referred to as A Level):

Many clearly feel that, without some form of bridging course, candidates obtaining a Grade B in mathematics on the Intermediate tier have an inadequate basis for moving on to AS and A2.
There is also unease that students entering engineering courses in HE with a highest mathematical attainment of GCSE Grade C could have studied for the Intermediate Tier; where teachers may have chosen not to teach algebra, given that the proportion of marks awarded to this topic in the examination is very low (Sutherland & Pozzi, 1995:8). The QCA (2006:12) in their interim report ‘Evaluation of participation in A level mathematics’, detail the piloting and evaluation of a new two-tier GCSE Mathematics course from September 2006.

G.7.1.3 Issues and Worries

That the mathematics encountered up to GCSE Level should enable post GCSE mathematics education, at a level that is comparable to that of other countries in the EU, is advocated by the LMS, IMA and RSS (1995:20). Gordon (2004:16) also compares mathematics education in England to that in other countries and writes:

It seems that England is one of the few countries where students can drop mathematics from age 16, and in theory need never pick it up again.

There have been numerous concerns cited regarding GCSE Mathematics and its position in the hierarchy of subject difficulty. Roberts (2002:74-75) discusses the prevailing view that science and mathematics in particular appear to be difficult subjects. The perceived difficulty of mathematics is also addressed in the Smith Report (2004:84), where it is suggested that many teachers and pupils hold this perception. Moreover, the amount of effort that is required to obtain a GCSE in mathematics is believed to be equivalent to that required to obtain both English Language and English Literature or to gain a double award in Science. The report also warns that this belief may be contributing to the feeling that mathematics is a disproportionately hard subject, which is having an adverse effect on the number of students who may choose to study the subject at a higher level. This perceived difficulty is also referred to in the response to the Smith Report where it is acknowledged that the attainment of grade C or above in GCSE Mathematics is below the level which is attained in many other subjects (DfES, 2004:5-6).
In 1996, Dearing, referring to representations from employers concerning standards in the application of number by their employees, stated “[these representations] have been a feature of national life for more than a century. It has always seemed that things were better 20 years ago” (Dearing, 1996:6). The issue of employer satisfaction is also addressed by Smith who collected evidence that suggests employers are not happy with the mathematical ability of their employees, even when they have achieved the minimum societal expectation of a grade C at GCSE. Moreover, from the point of view of many employers, GCSE mathematics is seen to be an inadequate preparation for the growing mathematical needs that are currently encountered in business and industry (Smith, 2004:86).

The value of a Grade C in GCSE Mathematics has also been damaged by media coverage relating to the low marks that are needed for this attainment. Smith (2004:86) expresses concern that an article in the Daily Express in the summer of 2003 reported that students were achieving a grade C in GCSE Mathematics with raw marks of 15%. In the 2006 GCSE examinations, where pass rates had risen for the 18th successive year, it has been established that pupils needed to obtain less than half the available marks to be awarded a grade A in GCSE Mathematics, with a grade C being awarded to students who only answered 16% of the questions correctly. Yet despite the low boundaries and high pass rates in other subjects, almost half those who sit GCSE Mathematics fail to obtain at least a grade C (Henry, 2006).

G.7.2 GCE A Level Mathematics

From the introduction of GCE A Level in 1951 until the mid 1980’s, the universities controlled its syllabus. It was primarily an entrance examination from which universities, in particular, could measure the ability of students seeking places at their institutions. From its inception the GCE A Level qualification was considered to be the ‘gold standard’ against which individual attainment could be measured. However, during recent years it has been suggested that the standard and status related to A Level has diminished. There have now been several changes to curricula and whilst a steadily-increasing percentage of pupils are obtaining passes and higher grades than was previously the case, there has, however, been a decline in the number of pupils taking...
GCE A Level Mathematics and a serious decline in the number sitting Further Mathematics.

Concerns surrounding Mathematics are not new; Thwaites (1972:5) reported that in 1961 academics were claiming that students entering HE did not know the basics and Cox (1994:11) discusses the issue that breadth has replaced depth in A Level syllabi. However, since 1995 the numbers of journal articles, press publications, and media coverage relating to issues surrounding A Level Mathematics has intensified. Gordon (2004:29) draws attention to the number of reports that are entitled “...Mathematics Problem...”. The report ‘Measuring the Mathematics Problem’, (Hawkes & Savage, 2000) whilst not constituting rigorous research, being in the main anecdotal in nature, nevertheless succeeded in focusing attention on the problem and prompted more rigorous research to be undertaken.

G.7.2.1 Syllabi - Changes and Content

From the implementation of the GCE A Level in 1951, the first major change to mathematics syllabi was the introduction of statistics in the 1970’s. This allowed students to choose from single A Levels in Pure, Applied, Pure and Statistics or Pure and Applied. Savage, Kitchen and Sutherland et. al., (2000:2), refer to the 1960’s as:

A “golden age” for A level Mathematics in which able sixth formers, aiming for university, were inspired and stretched by a very talented teaching force.

It seems evident that the introduction of statistics in the 1970’s was the first major point at which GCE A Level Mathematics syllabi began to lose their status as a defining measure of mathematical ability. The government became more involved with the curriculum and by the 1980’s universities no longer had control of syllabi. Courses are now validated by the QCA (Savage, Kitchen & Sutherland et. al., 2000:2).

After the implementation of GCSE Mathematics, it soon became obvious that there were significant problems for students as they moved, relatively unprepared, to the more demanding GCE A Level Mathematics syllabi. The implementation of new A
Level courses in the 1990’s resulted in mathematics syllabi containing an even wider range of options, namely, pure, mechanics, statistics and discrete mathematics. Savage, Kitchen and Sutherland et. al., (2000:2) describe the introduction of GCSE and the impact that it has had on A Level Mathematics:

At a stroke A level mathematics was undermined in a key area from which it has not yet recovered!

During the 1990’s there was a decrease in the pure mathematics core from 40% to 30% and many examining boards introduced modular syllabi. These changes along with the new diversity of choice aimed to make mathematics more popular and accessible (Savage, Kitchen & Sutherland et. al., 2000:2-3).

Further changes were introduced with Curriculum 2000 whereby students in the first year of A Level study were required to study 4 subjects at AS Level, continuing in the next year of their study with 3 of these subjects at A Level. These changes to the curriculum resulted in abysmal AS level results in mathematics, as students were required to sit examinations for 3 modules in the first year of study rather than 2, which had generally been the case previously. This resulted in a high failure rate and both Porkess (2003:12) and Smith (2004:8) report that, for mathematics, these reforms proved disastrous. It is reported by Porkess (2003:12) that in summer 2001 many students who had taken the AS Level in mathematics did not continue with the subject at A Level; this resulted in a decrease of approximately 12,000 students taking A Level Mathematics in 2002.

Prior to September 2004, modular A Level Mathematics examinations usually consisted of 6 modules, of which 3 were pure and 3 applied; however, from September of that year more changes were implemented. The content of the 3 pure modules became spread over 4 modules with only 2 applied modules being taken. Therefore, this new A Level is comprised of 5/6 of its previous content and cannot cover as much material as was previously the case, which is an issue of which universities need to be aware. On the other hand, as a result of the changes, AS Level Further Mathematics will now be available to more students, and students undertaking this qualification will have encountered more mathematics than was the case with A Level Mathematics prior to the
2004 changes (Porkess, 2003:16). However, it is too soon to determine the effects of these changes in relation to student achievement and uptake (QCA, 2006:4).

For a number of years there has been serious concern and debate regarding the content of GCE A Level Mathematics. Patrick (1996:9) draws attention to two differing points of view that exist with one faction claiming that the examination is more difficult than other subjects and the other claiming that the subject is not difficult enough as students with A Level Mathematics are ill-prepared for the demands that HE places upon them. She continues by stressing that these arguments are not productive and cites the work of Sutherland and Pozzi as being a more sensible approach. In an engineering context, Sutherland and Pozzi (1995:9) raise issues relating to the mathematical knowledge that can reasonably be expected from pupils with A Level and the mathematics that is actually required by engineering students.

It is not only the reduction of algebra and proof in GCE A Level Mathematics that is proving to be a cause for debate. Hibberd (1996:376) expresses concern over the number of available syllabi, which give rise to diversity in the areas of mathematics that students have encountered. There is also a wide choice of possible module combinations, and Hawkes and Savage (2000:iii) point out that the option of statistics, rather than mechanics, provides less underpinning of pure mathematics. It is also recognised that mechanics modules provide a firm foundation for engineering yet Robinson, Harrison and Lee (2005), in a survey of approximately 20% of the schools in England, determined that over a quarter of these schools offer at most one GCE A Level mechanics module.

After investigating the changes that have taken place in GCE A Level Mathematics, Hoyles, Newman and Noss, (2001:829) deliberate that “changes put in place to make mathematics more widely useful may result in it losing just those features that make it marketable”.

An interesting perception of the changes that have taken place in A Level Mathematics and the impact these have had on student understanding is given in Cox (1994:15) who cites a teacher describing the situation as:
A change from a small but deep pond in which students would swim and explore thoroughly, to a large shallow lake in which they can survive only by alighting on the odd stepping stone providing easy footing, such as partial fractions, inequalities, inverse functions and standard differentiation and integration.

G.7.2.2 Uptake and Pass Rates

The prevailing view that science and mathematics appear to be difficult subjects has led to concerns that teachers may, in some instances, be encouraging their pupils to choose non-science subjects at GCE A Level with a view to raising their ‘league table’ ranking. Whilst there is little more than anecdotal evidence for this suggestion it is considered to be an issue worthy of government consideration (Roberts, 2002:75). The same issues are addressed by Smith (2004:13), with the additional comment that this perceived difficulty has implications for students who are seeking the grades at GCE A Level, which will enable them to obtain a place at the university of their choice. He considers these issues to be a contributing factor to the number of students who continue to study mathematics at A Level. The issue of school league tables and examination results has also been referred to by Gill (1999:84), who reflects that a result of this is “teachers teaching to the test”, and continues:

This has always gone on to some extent and it is probably unavoidable. However, the emphasis on league tables has increased the pressure. This is producing cohorts of students who are good at passing certain styles of examination regardless of content.

Between 1989 and 2000 there was, overall, a reasonably steady growth in the number of students taking A Levels, from 661,591 in 1989 to 771,809 in 2000. However, during the same period, the percentage of candidates taking A Level Mathematics had been in almost steady decline, mathematics accounted for 12.8% of the total in 1989 and had fallen to 8.7% by 2000. As a result of Curriculum 2000, the overall number of A Level Mathematics candidates fell from 67,036 in 2000 to 53,940 in 2002. By 2003, the percentage of candidates taking A Level Mathematics had dropped to 7.5% (Porkess, 2003:13). Another significant change has been the number of students who take two A
Levels in Mathematics (these qualifications are now referred to as Mathematics and Further Mathematics). Since 1965 there has been over a 60% reduction in students taking Further Mathematics (LMS, IMA & RSS, 1995:12). The same issue is also raised by Hoyles, Newman and Noss (2001:834), citing Heard, they report that in 1997, in England and Wales, only 12% of students undertaking A Level Mathematics also studied Further Mathematics A Level compared to 36% in 1965.

On an almost yearly basis since the mid 1980’s there have been concerns regarding the increase in A Level pass rates and grade achievements. There exists an annual event of newspaper headlines and television coverage suggesting that grade dilution is taking place and A Levels are becoming easier. The headline of a Daily Mail article by Clarke and Harris (2002) stated “A-levels: A 100% Pass Rate by 2004”. One exception to this was in the summer of 2002 when newspapers raged about the ‘A Level scandal’ and students being cheated from obtaining higher grades, which prompted the government initiated inquiry into A Level standards. Many syllabi contain some coursework, which enables students to submit work without the pressure of an examination. However, this is now under investigation and on the 6th October 2006 the QCA announced that coursework will be removed from Mathematics GCSE syllabi (http://www.qca.org.uk/2586_17443.html). Additionally, the modular examination system allows students, if they wish, to re-sit examinations in an attempt to improve their overall A Level grade.

Prior to 1986 there was a more or less fixed percentage of the cohort that would be awarded each grade. The LMS, IMA and RSS (1995:15) investigated A-Level standards and detailed the following percentages for A Level Mathematics, prior to 1986 as, “Grade A was awarded to about 10% of the candidates, Grade B to 15%, Grade C to 10% and so on with 30% being condemned to fail”. There has been an increase in the percentage of higher grades obtained and in 1994 these were “A 25%, B 18%, C 16.5%, ‘Fail’ 15%”. The evidence presented to the group did not suggest that the 1994 percentage that obtained Grade A in A Level Mathematics performed at a level that was comparable with the percentage obtaining the same grade prior to 1986. They continued by writing:

There is no doubt that there has been, in an obvious sense, a devaluation of grades.
More recent A Level Mathematics results listed by Smith (2004:63) show that the number of candidates obtaining a Grade A had risen to 39% in 2003. In relation to the distribution of grades, comments received from respondents suggest that:

The more able students entered for A-level mathematics are insufficiently challenged and the least able are frequently overstretched. (Smith, 2004:94).

That it is difficult to compare modular courses is acknowledged by Roberts (2002:71). He explains that whilst there have been changes in the characteristics of examination papers between 1975 and 1995 the standard of A Levels has been maintained. Tomlinson (2002:8) refers to the importance of measuring students’ performance at A Level against a predetermined level rather than against that of their peers and writes:

If 100% of students reach the standard then 100% should pass, and that outcome should not be seen as a ‘lowering of standards’.

Preliminary findings from the Nuffield Review of 14 to 19 learning confirm that problems with numeracy, amongst even the brightest students, are commonplace (Times Higher Education Supplement, February 10th 2006). A final year project (unpublished) undertaken by Wright (2002) at Loughborough University to investigate the question ‘Is A-Level Mathematics Becoming Easier?’ concluded:

Overall, the results and implications of both the personal analyses and the survey lend weight to the contention that A-Level Mathematics examinations have become easier and there is confidence that this conclusion holds a credible amount of validity...

G.7.2.3 Issues and Worries

“Mathematics matters” are the opening words written by Tikly and Wolf (2000:1), who continue by cogently summarising the importance of mathematics for the UK in the 21st
century and the place that teachers have in this process. However, they make the worrying observation:

Yet in the United Kingdom, mathematics education is in crisis, and, with it, individual opportunities for development and the future economic prosperity of this country. We cannot recruit or retain the mathematics teachers that we need, so that, already, large numbers of our pupils are in mathematics classes without a mathematically qualified teacher. We are creating a vicious circle, whereby a poor supply of mathematics teachers today ensures an even greater shortfall in the future; a shortfall not only in teacher supply but also in the abilities and understanding of a whole generation.

They conclude that this can only damage the quality of degrees in a wide range of key disciplines. This belief that mathematics education is in crisis is also endorsed by Mustoe (2002:69) with the added comment that “it is in danger of being in free fall”.

A large number of competent mathematics teachers are now in their 40’s and 50’s and will shortly be retiring without experienced replacements being available to fill their places. With the broadening of mathematics syllabi and the range in ability and background of pupils the task of the mathematics teacher has been getting progressively more difficult and pressured, and:

Even good schools are finding it almost impossible to recruit acceptable new mathematics teachers. Many posts are filled mainly by people who are not mathematicians and do not have a sound background in the subject. (Savage, Kitchen & Sutherland et. al., 2000:4).

Smith (2004:3) confirms that the shortage of specialist mathematics teachers is an area of concern, and identifies that there is a need to “support and nurture all teachers of mathematics”. One important issue related to the teaching of mathematics is that of the combination of subjects being chosen at A Level. In 1965, 38% of students taking A Level were studying mathematics and science; however, by 1993 there were only 16% of A Level students studying these topics. Students are often encouraged to choose a selection of A Level subjects from both the arts and science, whilst this results in a broader education, the deeper understanding that would have been gained by studying, for example, mathematics and physics, is being lost (LMS, IMA & RSS, 1995:12).
It is pertinent to mention that A Levels now cater for a wider range of ability than was previously the case. The role of A Level Mathematics has changed to that of an accessible part of general education and is “no longer being designed as a tool for serving the needs of university mathematics” (Hoyles, Newman & Noss, 2001:838-842). Kent and Noss (2003:9) highlight the fact that “it is now accepted that A-level no longer provides what it used to as a preparation for university study and significant steps are now under way to reform the whole school mathematics curriculum”. The changes that have taken place in the school curriculum are also succinctly acknowledged by Croft, Hibberd and Lawson et. al., (2000:78) with the contribution “certain skills, well developed in the past, can no longer be assumed, particularly in algebra”.

G.7.3 Mathematics in Higher Education

That the radical changes made to the pre-19 mathematics curriculum would have a serious impact on HE is not surprising. Since the arrival at university of the first candidates who had taken the GCSE examinations, there have been numerous journal articles concerning the mathematical accomplishment of these students. Problems are now experienced in numerate disciplines throughout the HE sector and there is a growing need for additional mathematics support and remedial measures.

The concerns that were being raised by academics regarding the mathematical ability of incoming students led to a number of investigations being undertaken. In 1994 the Engineering Council commissioned a report to investigate speculation and anecdotal evidence concerning the changing mathematical background of undergraduate engineers. In 1995 the LMS, IMA and RSS investigated concerns amongst mathematicians, scientists and engineers in HE about the mathematical preparedness of new undergraduates. On a wider scale, the Gatsby Charitable Foundation sponsored a seminar in 1999 to investigate the same issue but in Departments of Mathematics, Physics and Engineering. Section 2.3.3.1 details the reported difficulties, findings and recommendations from these, and other, investigations. The particular problems that are being reported by academics are covered in section 2.3.3.2, section 2.3.3.3 looks at the effects these changes are having on students, lecturers and mathematics departments.
and section 2.3.3.4 investigates the measures that have been taken by universities to alleviate the problems.

G.7.3.1 Reported Difficulties, Findings and Recommendations

Initially, evidence regarding the decline in students’ mathematical expertise was anecdotal, with comments being made that students were unable to cope with basic mathematical concepts and even those students who had obtained high grades were experiencing difficulties with algebra and calculus. It was these concerns that led the LMS to establish a working group to identify the difficulties and to make suggestions for improvement. Since the mid 1990’s this difficulty, perceived by those in HE, has been referred to more explicitly and concisely as a decline in the ability of incoming undergraduates (Savage, Kitchen & Sutherland et. al., 2000:3). Kent and Noss (2003:9) also refer to the problems that have arisen since the mid 1990’s, whereby in numerate degree courses there is a breach between the expectations of those in the HE sector and the mathematical ability of incoming undergraduates.

The primary finding of the LMS, IMA and RSS (1995:5) is that there exists a serious problem in the UK regarding the declining and inadequate number of undergraduates embarking upon mathematics, science, engineering and technology courses, and also, with the inadequate mathematical preparedness of students on these courses. That there has been a steady decline, since the 1990’s, with the use and familiarity of what are considered to be basic mathematical skills is upheld by Hawkes and Savage (2000:iii). They confirm that there is a lack of preparedness amongst undergraduates for the mathematics that they will encounter and make it known that, across the whole spectrum of universities, there are difficulties being encountered by those staff who teach modules that are dependent upon mathematics. Likewise, Sutherland and Pozzi (2000:5), determined that amongst engineering students their mathematical knowledge was weaker than it had been ten years previously.

Claims made by academics in HE that there was a serious decline in students’ ability to deal with algebraic manipulation, to deal with multi-step problems, and a lack of understanding relating to the importance of precision and proof within mathematics
were investigated. That these criticisms are justified was upheld by the LMS, IMA and RSS (1995:2, 10-11), who failed to find any evidence to the contrary in their investigations. Dearing (1996:96) refers to the need for more algebra in A Level and mentions the concerns that have been expressed regarding limited perceptions of the role of precision and proof.

Criticism from Mathematics, Science and Engineering Departments in HE of incoming students’ lack of mathematical fluency and reliability in numerical and algebraic manipulation, their decline in analytical powers compared to that of the early 1980’s and their lack of comprehension that mathematics is a precise discipline were investigated and found to be justified (LMS, IMA and RSS, 1995:8-11). This is in accord with one of the issues of major concern identified by Smith:

“The failure of the current curriculum, assessment and qualifications framework in England, Wales and Northern Ireland to meet the needs of many learners and to satisfy the requirements and expectations of employers and higher education institutions. (Smith, 2004:3).

Another issue is that whilst recent changes may have been advantageous for some pupils, they have disadvantaged those who continue to study mathematics beyond school (LMS, IMA & RSS, 1995:2). This is in accord with Kent and Noss (2003:9, 24-25) who also add that it is agreed by all who are involved with mathematics in the UK that A Level Mathematics no longer provides the building blocks for those courses in HE, which contain a mathematical element. There are several causes, which underpin the mathematical difficulties that are being encountered; these include the many different topics that may or may not have been covered at A Level and the small core of material that is common to all syllabi. These difficulties are also compounded by the fact that many students have not undertaken any mechanics modules and there has been a noticeable decline in their knowledge of calculus. A questionnaire that was distributed by Kent and Noss during their investigation identified calculus as “a near-universal problem”.

- 449 -
Given the divergence of the school mathematics curriculum and the level of mathematical competence that is expected by HE institutions it is not surprising that many students enrolled on engineering and mathematically-based undergraduate courses find the mathematical content beyond their grasp. Undergraduate courses frequently commence at a level above that encountered in A Level syllabi. Furthermore, even students with good A Level Mathematics grades often possess insufficient knowledge or ability to use, successfully, the mathematical techniques that are expected at university. This has resulted in many universities running some form of remedial course for their new undergraduates to enable them to progress through their chosen degree programme. In a 5-year review of standards, the QCA, in 2001, found that between 1995 and 1998 the pure mathematics content of GCE A Level was generally “less algebraic and more structured or tested to a less demanding level”, with variability existing between different examination boards (Roberts, 2002:8, 89-90).

The reduction of algebra in GCE A Level syllabi, since 1995, has given rise to greater emphasis being placed on problem solving in real-life situations, with a consequent reduction in the more formal presentation and abstract application of mathematics. Evidence from HE suggests that these changes have resulted in “a generation of young people who have extreme difficulties in using mathematics at all, whatever the context”. This gap between what incoming undergraduates know and what universities would like them to know is, however, not only due to changes in the curriculum. On some courses where universities are experiencing difficulty in sustaining recruitment levels, such as engineering, they are not in a position to demand the mathematical qualifications that they would ideally like the incoming students to have (Sutherland, 2000:75-77).

The diversity and range of qualifications with which students enter undergraduate courses is also a problem (Hawkes & Savage, 2000:iii). Students without a qualification beyond GCSE Mathematics are inadequately prepared for any degree course which has a mathematical requirement. It is not only that topics encountered in GCSE are covered in insufficient depth, but also that the recall of these topics inevitably diminishes during the intervening years between obtaining the qualification and entering university. It has also been found that for students entering engineering and science disciplines, the Advanced GNVQ qualification does not adequately prepare them for the mathematical elements of their courses (Sutherland, 2000:82-83). The Advanced GNVQ is deemed to
be equivalent to two GCE A Level passes (Holt, Andrews & Boyd et. al., 2002:233). This is in accord with Lawson (2000:89-92) who has determined that, at Coventry University, students who have obtained Advanced GNVQ qualifications are less well prepared for university courses, with a mathematical content, than students from the traditional A Level route whatever their achieved grade.

With incoming cohorts, on some undergraduate courses, possessing such a wide range of mathematical knowledge and ability, it has become necessary for universities to provide some form of support to enable them to cope with the demands of their chosen degree. It is not viable for universities to teach students, with this range of ability, the underlying body of mathematics that is needed to enable understanding of the material being encountered at undergraduate level. Academic staff should be involved with communicating the intricacies of their particular discipline, not with teaching the basic mathematics that is needed for progression (Sutherland, 2000:84). For those students with a weak mathematical background, the level of support that they require is generally unavailable at universities. Whilst many institutions provide some form of mathematical support, there is evidence that this support does not meet the requirements of those who are most in need of it (Sutherland, 2000:81).

It is also becoming apparent that the problems being encountered at undergraduate level are affecting the numbers who continue to postgraduate study. In March 2005, key personnel met to discuss the question “Where will the next generation of UK mathematicians come from?” Their report not only noted “the failure to produce an adequate supply of high quality, home-grown graduates” but also referred to this lack of UK postgraduates, stressing that “in order to maintain the quality of postgraduate recruitment, public funds are increasingly being used to support students from other – mostly EU – countries” (Manchester Institute for Mathematical Sciences, 2005).

The arguments that have been offered, so far, all support the view of a mathematical deficiency in the majority of students entering undergraduate courses with a quantitative element. Whilst what has been written might be perceived to be a one-sided argument, the literature is almost all in accord with the problems and difficulties that have been expressed here.
Nevertheless, referring to the 1995 changes to A Level Mathematics, which resulted in the loss of some topics such as complex numbers and partial fractions, Porkess (1996:359) concludes that:

Those university lecturers who are complaining about the loss of these particular topics from A level Mathematics are missing the point. What they are observing is a completely different effect: that they are now accepting single subject students who have not done Further Mathematics.

The suggestion that universities have not taken sufficient action to address the problems has also been raised. Thomson (2004) reports that Professor Smith, when speaking to The Times Higher, after submission of his report ‘Making Mathematics Count’, commented that:

Universities have a legitimate evidential whinge that competencies in maths are not what they were ten or 15 years ago, but they could have done a lot more to help solve the problem rather than just identifying it.

However, the continuing existence of universities shows that they have responded to the changes in the mathematical background of their incoming students. The changes that have taken place include the redesigning of first year courses, the provision of supplementary courses in mathematics, the introduction of workshops, small group teaching and the running of preliminary courses. Moreover, individual institutions are shouldering the financial implications of these measures (Sutherland, 2000:83).

It is recommended that all new undergraduates, commencing courses with a significant mathematical element, should have a diagnostic test on entry to university. In 1999, it was established that in at least 60 departments of mathematics, physics and engineering, the administering of diagnostic testing, to new undergraduates, was taking place. These diagnostic tests play an important role in identifying those students who are at risk of failing, either due to their mathematical weaknesses or to their inadequate mathematical background. After identification these students can be provided with additional support. Once mathematical shortcomings, amongst incoming undergraduates, have been identified, programmes can be designed to match the general range of ability of these
students, thus helping to remove any unrealistic staff expectations. It is also necessary to provide prompt and effective support to those students who are deemed as a result of diagnostic testing, to be at risk (Hawkes & Savage, 2000:iii-iv).

Whilst it is not feasible that GCE A Level mathematics syllabi can return to that of approximately 15 years ago, it is important that the role of this qualification, as a basis for degree level study, in science, technology, engineering and mathematics courses, is considered. The QCA and other awarding bodies, in reviewing the content of GCE A Level and AS Level qualifications, must consider this issue. Additionally, HE institutions must realise that it is not beneficial to overload the content of GCE A Level Mathematics and they should have some flexibility regarding the ability and knowledge of incoming students (Roberts, 2002:90).

It is also recommended that HE institutions should examine and adjust their courses in science, engineering and particularly mathematics to help students make a smooth transfer from school to university. This would be especially beneficial to those students who would previously have been unlikely to enter HE. The government should also fund HE institutions to run support courses and use e-learning programmes to assist students with the transition to HE. To prevent students being discouraged from reading science and engineering subjects, the government should, in three years time, review the progress that has been made in reducing the mismatch between GCE A Level Mathematics and the starting point of undergraduate courses with a mathematical content (Roberts, 2002:93).

The government, in their response to the Smith report, have published details of the measures that are to be taken to address the problems that were raised. These include the establishment of a ‘National Centre for Excellence in the Teaching of Mathematics’, the viewing of proposals for changes to the 14-19 curriculum that will stretch the most able and extend the availability of Further Mathematics through the provision of centres for this purpose (DfES, 2004:34, 39,43). It is not yet possible to comment on the success or failure of these proposals as the students being subjected to these endeavours have not yet arrived in HE institutions.
Research has also been undertaken by a member of the National Teaching Fellowship Scheme to evaluate the quality of provision of service mathematics teaching. Egerton (2000:7) emphasises that the issues relating to mathematics support must be given serious attention.

As aspects of mathematics are embedded in so many subjects – indeed mathematics can be said to be embedded at the core of our culture – it is vital that we investigate and focus on the best practice in supporting student learning in our area.

G.7.3.2 The Voice of Academics

Not only are there problems with GCE Mathematics but the situation has arisen whereby students are entering university courses, for which GCE A Level is not a pre-requisite, with only a rudimentary knowledge of mathematics. These students lack basic mathematical skills and are faced with the need to take remedial action.

It is explained by Croft (2000:22) that mathematically weak students, in addition to coping with the progression of their course, also need to spend extra time and effort to address their underlying lack of knowledge. This rarely seems to work and the disparity between the expectations of university departments and the ability of incoming undergraduates often results in, “a tremendous amount of unhappiness and misery for the affected students, and puts teaching staff in a no-win situation”. This is also endorsed by Mustoe (2001), who elucidates that mathematical knowledge cannot be acquired quickly and it is not possible for students to fill in the missing pieces of underlying pre-requisite knowledge and at the same time cope with their ongoing undergraduate course.

One area that has given rise to numerous publications, is the near absence of mathematical proof in GCE A Level syllabi and examinations since the 1990’s. Cox (1994:11-21) raises the issue regarding the disappearance of proof from GCE A Level examinations and suggests that it should be both reintroduced into the school mathematics curriculum and also assessed. He also suggests that many pupils are able to
obtain good results at GCE A Level by, “strategic learning”. This, he explains, is where students put their efforts into learning standard topics that are likely to be examined at the expense of acquiring a deep understanding in key areas of mathematics.

Anderson (1996:129-134) elaborates on this absence of proof, pointing out that whilst mention is made of concepts such as ‘proof’ or ‘counterexample’ in A-Level syllabi “few examination questions are set which demand any depth of understanding or which require any creativity in the process of justification”. He also mentions the demise of traditional Euclidean geometry from syllabi and the fact that pupils now encounter algorithmic techniques (mainly algebraic) which do not require abstract thinking into what is actually happening. He continues by citing the example of proof by induction, stating that, for students:

Most do not understand why proof by induction is a valid method of justification and indeed regard it as a confidence-trick.

He also emphasises that the little proof that was in GCE A Level syllabi had, in the 1996 syllabi, been relegated to Further Mathematics; and concludes that it is worrying that a large number of incoming undergraduates display a lack of knowledge and naivety about the reason for and purpose of proof, with many students being unaware of the mathematical tools that are available to them. He advocates that there is nothing to suggest that this state of affairs will improve and recommends that it would be beneficial if students were exposed, at an earlier date, to notions of proof.

That the situation has not improved is confirmed by Almeida (2000:869-890), who explains that changes to the curriculum in the 1980’s and 1990’s, whilst broadening the range of mathematics encountered at school, have resulted in the near extinction of proof from syllabi. This has, in turn, led to difficulties being encountered by students when they encounter proof at undergraduate level.

Other areas in which students are repeatedly reported to experience difficulties and exhibit weaknesses are with algebra and with rigorous application of the mathematics they encounter. At an International Congress on Mathematics Education (ICME-9, 2000), the Working Group WG5A reported that speakers, from several countries, had
expressed concern that new undergraduates are now less familiar with algebra, traditional mathematics and the rigour with which mathematical techniques should be applied. However, on a more positive note, it was also mentioned that new undergraduates do arrive at university better prepared for group work and the technology they encounter than was previously the case. Gill (1999:86-87) and Gordon (2004:16) found that many students are not able to cope with the mathematics they encounter at undergraduate level, are weak in their understanding of basic concepts and unable to apply mathematical techniques in the context of their chosen discipline. A significant challenge is emerging for mathematics departments who are struggling to preserve the integrity of their mathematical programmes and at the same time meet the needs of the departments for which they provide service teaching (ICME-9, 2000).

In 2000, as detailed earlier, Hawkes and Savage recommended the introduction of diagnostic testing for all new undergraduates in disciplines where mathematics played an integral part. Results of diagnostic testing, which has been undertaken over a period of years, have not only identified those students who are considered to be at risk of failing the mathematical elements of their course but have also served to emphasise the decline in mathematical ability of incoming undergraduates. Lawson (1997:155-156) administered diagnostic testing at Coventry University between 1991 and 1997 and determined that there is little difference between those students who entered the University in 1991 with GCE A Level at grade N and those entering in 1997 with GCE A Level at grade C.

Lawson, in the report ‘Measuring the Mathematics Problem’, cites Professor Mathew of the University of York who has used the same diagnostic test on incoming undergraduate physicists from 1979 to 1999. This testing showed that there was little change in performance until 1990. In 1990 there was a noticeable decline in achievement followed by a steady decline from 1991 to 1999 (Lawson, 2000a:10). This trend is also confirmed by Todd (2001:152-156) who has demonstrated that over a 15-year period, students in an engineering department at the University of York, with apparently identical GCE A Level grades, have shown, as a result of diagnostic testing, a severe decline in their mathematical skills. Speaking at a seminar held at Loughborough University on 3rd November 2004, Todd explained that he is no longer administering diagnostic testing to engineers in his department as the results being
obtained are no better than those which could be achieved by random guessing by the students.

Academic staff are not just bemoaning the mathematical ability of incoming students, they are painfully aware that there is now a gap between the starting point of many courses and the ability of incoming students. Cox (2001:847-861) using the results of diagnostic testing has compared the expectation within HE of students’ knowledge with their probable preparedness in a range of topics. He found that whilst some departments do have realistic expectations regarding the knowledge of incoming students, others seem to have expectations that exceed student capability. Sleeman (2000:25) explains that it was this gap between expectation and ability which prompted the introduction of diagnostic testing at the University of Leeds, with subsequent follow-up support being offered.

Even with lecturers’ awareness of the ability of incoming students from traditional backgrounds, and of those entering university as a result of the government-driven endeavour to widen participation, there still remains a gulf between the expectation by lecturers and the realistic achievement of students. Students with high grades now struggle with concepts that would have been easily mastered ten years ago. This variability of knowledge within the student cohort makes it difficult for lecturers to deliver topics at a level that will suit the majority of the group (Mustoe, 2002:67-69).

Savage and Croft (2001), whilst acknowledging that universities must support students with a weak mathematical background, also explicate the question of whether there is a problem with mathematics at university:

The Universities are in no doubt – there is a problem and it has been getting worse since 1990.

G.7.3.3 Effects of the Changes in Mathematical Background

An increasing number of young people in the UK are now entering university and the gap between the mathematics that is taught at school and the mathematics that is
encountered upon entry to university, is proving to be a barrier to progression. Whilst policy makers might take the view that students will be able to learn what they need when they need it, the evidence from HE is that this is not the case (Sutherland, 2000:101).

There is an indication that the mathematical content of many engineering degree programmes are being modified to match the mathematical background of the incoming students (Sutherland & Pozzi, 1995:9). However, whilst this might help to avoid a high drop-out rate of students with a weak mathematical background on engineering courses, it impedes the progress of the more mathematically competent students (Croft, Hibberd & Lawson et. al., 2000:78-79).

Kent and Noss (2003:15-16), in their report to the Ove Arup Foundation, recognise that, in an engineering context, “Mathematics is both a problem and an opportunity for universities”. There are opportunities arising through the growing power of computers to break new frontiers in civil engineering construction, whereas problems are evident in the mathematical education of students. Pyle (2001) spells out the problem that is being experienced in universities:

Each year the A-level results come out showing increased pass rates, yet we do not see any improvement in the ability of students to tackle the mathematics of engineering degree courses. ... The situation is serious, and getting more so. Most university engineering departments now find it necessary to provide remedial teaching for students whose mathematical foundations are not adequate for university first-year maths. ... The problem does not diminish in later years, as students need to have absorbed the mathematics of the earlier year before they are ready to advance to more advanced material.

Universities in the UK do not have the resources to cope with the diversity of mathematical knowledge that first year undergraduates bring to their institutions and it is not feasible for them to have to teach students from such wide-ranging backgrounds (Tikly & Wolf, 2000:1; Sutherland, 2000:85). Not only is it recognised that there is pressure on departments to reduce the mathematical content of courses to match the incoming student ability but there is also a need to minimise the student drop-out level.
to avoid loss of revenue. This has resulted, in some disciplines, in students being allowed to progress through their course even if they fail their mathematics modules. Additionally, there is a perception that the effectiveness of an institution, might be judged, by the number of first class and upper second class honours degrees that it awards (LMS, IMA & RSS, 1995:23).

LMS, IMA and RSS (1995:23), Sutherland (2000:84) and Mustoe (2002:68) are all in agreement that these pressures are likely to devalue the quality of degrees that are awarded. If the mathematical ability of students in the UK is less than that of other countries in Europe, this raises the serious issue that the UK will become more dependent on European countries for inventions, specialists and products. “It is essential that our national aims and objectives for education in mathematics should take full account of what is being achieved in other countries” (LMS, IMA & RSS, 1995:6, 19).
This is endorsed by Croft, Hibberd and Lawson et. al., (2000:78-79) who emphasise that consideration must be given to the provision of an adequate mathematical content to ensure that UK students are not disadvantaged when compared to students from elsewhere in Europe. Gordon (2004:29-30) also cautions:

If universities do allow mathematics departments to wither, the knock-on effect could be immense. ... As a country, we are in danger of letting mathematics suffer long term damage.

**G.7.3.4 Measures Taken by Universities to Address the Problems**

Many universities, as mentioned previously, now use diagnostic testing to identify those students who are likely to experience difficulties with the mathematical element of their course. Those students who are identified as being at risk of failing are then often given follow-up support. It is emphasised by Savage and Croft (2001) that providing follow-up support is often difficult, nevertheless, universities are undertaking many different measures to provide such support. These measures include grouping by ability and teaching these groups separately, employing school teachers to teach, rather than lecture, the weaker groups, extended teaching hours and the introduction of remedial lectures.
In addition to diagnostic testing many universities now administer CAA on a regular basis, not only to encourage students to work throughout the semester but also to obtain ongoing information about student ability and areas of difficulty that are encountered. A great deal of work has gone into improving this form of testing and it is possible to provide constructive feedback. Greenhow, Nichols and Gill (2003, 25) explain that incorrect input, as a result of commonly made errors, can be recognised and feedback such as “You have forgotten to divide by 2” can then be given. It is not only incorrect answers that have the potential for feedback, Greenhow (2000:24) gives the example of a question asking for $10^2 \times 10^3$ to be evaluated with answer options including $10^5$ and 100,000, which are both correct. For students who selected 100,000 the feedback “Are you using a calculator? If so please don’t!” could then be given.

Other routes that have been taken by university departments, to cope with the teaching of mathematics to first year undergraduates, include the redesigning of first year courses in mathematics, the provision of remedial assistance, drop-in support and computer based mathematics learning centres (Savage, Kitchen & Sutherland et. al., 2000:3). Sutherland (2000:83) cites the introduction of additional maths courses and small group teaching by universities as evidence that they are attempting to deal with the changing mathematical background of incoming undergraduates. More recently, some universities have introduced summer schools, which teach fundamental basic mathematics and are attended by students prior to the commencement of their undergraduate courses and other universities include a portion of foundation material in their first year mathematics courses. Support is also provided via workbooks and computer based learning and many universities have also introduced mathematics learning support centres (Gordon, 2004:21, 27-29).

A survey of 106 universities in the UK found that more than 60% of them are offering some form of mathematics support to their undergraduates. This support ranged from peer support to fully staffed mathematics learning support centres and is discussed in Chapter IX. Amongst those universities that did not offer learning support there were several who would like to implement some form of support but were unable to obtain funding to do so (Perkin & Croft, 2004:14-18). For those universities who would like to introduce some form of mathematics support, there is literature available to help them;
Lawson, Croft and Halpin (2003) have authored a guide to the establishment and development of mathematics support centres in HE.

A booklet entitled ‘Maths Support for Students’ published by the LTSN MathsTEAM Project is freely available (http://www.ltsn.ac.uk/mathsteam). This publication disseminates current practices and measures that have been taken by universities, across the whole spectrum of HE, to deal with the challenges that are being faced. Examples of the support that is on offer include a three-stream mathematics system whereby students are allocated to one of three different streams according to their pre-university qualifications and the results from a diagnostics test taken on entry. They are then taught and examined at an appropriate level. Many universities now send Algebra Refresher and Calculus workbooks to students prior to their entry to university. Additional lectures, bridging courses, transition modules and summer schools are also increasingly being provided.

Leeds, Loughborough and Coventry Universities, the ESB Trust, Media Inc and several of the Learning and Teaching Support Network (LTSN) Subject Centres have developed a national support framework to help students with the transition from school mathematics to university mathematics. The support is provided through the mathcentre website (www.mathcentre.ac.uk), and a DVD-Rom disk set, mathtutor.

On a broader scale, there is evidence of an unacceptably wide chasm between the number of children from working class backgrounds entering university compared to those from professional backgrounds. In some areas children from professional backgrounds are five times more likely to enter university than those from working class backgrounds. Universities are being proactive in their endeavours to widen participation by working with schools and colleges in low participation areas in an attempt to widen access (DfES, 2003: 17, 70).

Additionally, HE institutions have now become involved in addressing the problem regarding the lack of availability, in some schools, of the option to take Further Mathematics GCE A Level. Participating universities are teaching this subject, at their own institutions, to pupils in their locality.
It is difficult to envisage what additional measures could feasibly be implemented by the HE sector.

All references for this Appendix are included in the references contained in the printed thesis (see pp336-348).
APPENDIX H: Case Study as a Research Method

H.1 The History of Case Study

Case studies have long been an accepted research method in areas such as law and medicine. In other fields they have been the subject of much controversy and criticism, being cited as unscientific and not recognised as an acceptable method of research.

Since the late 19th century there has been rise and decline in the popularity and acceptability of case study. At this time the Chicago School was a leader in the field of qualitative research using case study and influenced American sociology. However, by the 1920’s there was increasing debate regarding qualitative and quantitative methods of research. Until 1935 there were no doubts regarding the pre-eminence of the Chicago School in sociology, however, the statistical survey gained ground at Columbia University with the result that rivalry developed and disputes over case study became rife. In 1935 these differences culminated in a public dispute between the Chicago School and Columbia University. The result was victory for Columbia University. There then followed a decline in the use of case study as a research method until, in the 1960’s, researchers became concerned about the limitations of quantitative methods and interest in case study and qualitative methods was renewed. This renewal in case study research was helped by a number of respected case studies (Hamel with Dufour & Fortin, 1993:18-27, 57).

Many educational research texts (for example, Anderson, 1988; Bogdan & Biklen, 1982; Burns, 2000; Cohen, Manion & Morrison, 2000; Robson, 2002) include a chapter describing case study; however, they include insufficient detail to enable a researcher to perform a meticulous study. Robert Yin, a leader in the field of case study research in the social sciences, has produced comprehensive texts detailing the necessary steps that must be followed in order to conduct a case study in a rigorous and scientific manner. Indeed, Robson (2002:178) writes that Yin has:

Done much to resuscitate case study as a serious option when doing social research.
However, it is pertinent to mention that Yin (1993) also gives examples of the use of case study outside the field of social sciences; in particular, he dedicates a chapter of this text to case study design in educational research.

H. 2 When is Case Study a Suitable Method for Research?

Research may be considered as a systematic inquiry, which aims to increase knowledge, understanding and awareness in a particular area. The educational texts, mentioned previously, take the view that the case study method is especially suited to individual researchers; yet they often do not provide adequate detail to enable the researcher to determine whether the research questions being posed are well suited to this method.

The first stage is to conduct a thorough search of literature appertaining to the area of research in question; this is imperative in order to avoid duplicating work that has already been undertaken. It also highlights areas where little research has been undertaken. As a result of this literature review, research questions may then be posed, it is these questions that have a bearing on which research strategy is most suitable for the research being undertaken. A question such as ‘what problems are experienced in mathematics by dyslexic students in higher education?’ is exploratory in nature and any one of several different research methods, such as a survey or an experiment, is suitable. The case study has a distinct advantage when a ‘how’ (as opposed to a how many or how much) question or a ‘why’ question is posed about a contemporary group of events, which the investigator has little or no possibility of controlling (Yin, 2003:6-9). For example, ‘how’ a community coped, over a period of time, following a catastrophe is particularly suited to case study, whereas ‘how many’ times an event has occurred over a period of time is more suited to quantitative research.

In a text relating to applications of case study, Yin (1993:23-31) describes case study as an appropriate method of research when trying to ascribe causal relationships, rather than just writing a descriptive scenario or describing a situation by detailing illustrative results.
Several other well-known authors in the field of case study research, which include: Merriam (1988:xii), Anderson (1998:152) and Bassey (1999:xii), express the point of view that case study is an appropriate method for educational research. Furthermore, Yin (1993:41) berates the fact that case study research remains an unappreciated and under-used method by those in the field of education.

H.3 What is the Case Study Method?

There are many descriptions of case study, a selection of which is given later in this section. The definition of case study given in The Oxford English Dictionary (1989:935) is:

- case-study, the attempt to understand a particular person, institution, society, etc., by assembling information about his or its development; the record of such an attempt.

It is difficult to explain in a few words exactly what constitutes a case study, still less, a ‘good’ case study, as it involves the collection and analysis of data followed by presentation of the evidence relating to the unit of analysis, and does not follow a specific recipe. It is illustrative, it can be used to complement a large-scale survey or as a stand-alone research method and it is concerned with the interaction of factors in a real context. The most commonly-held view is that case studies are only suitable for qualitative research, but Yin (2003:15) explains and later gives examples of situations where:

- They may be based on any mix of quantitative and qualitative evidence.

Another description of case study is that given by Sturman in a text edited by Keeves (1997:61):

- “Case Study” is a generic term for the investigation of an individual, group or phenomenon. While the techniques used in the investigation may be varied, and may include both qualitative and quantitative approaches, the distinguishing feature
of case study is the belief that human systems develop a characteristic wholeness or integrity and are not simply a loose collection of traits. As a consequence of this belief, case study researchers hold that to understand a case, to explain why things happen as they do, and to generalize or predict from a single example requires an in-depth investigation of the interdependencies of parts and of the patterns that emerge.

Cohen, Manion and Morrison (2000:185) dedicate a chapter of their text entitled ‘Research Methods in Education’ to Case Study with the description that:

…the case study researcher typically observes the characteristics of an individual unit – a child, a clique, a class, a school, or a community. The purpose of such observation is to probe deeply and to analyse intensively the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalizations about the wider population to which that unit belongs.

Case study involves many different methods of data collection, which include interviews, documentary evidence, surveys and observation, and may reveal far more detail than that which can be obtained from just surveys and questionnaires. Anderson (1998:160) makes the contribution that case studies can be both revealing and interesting to do but Yin (2003:17) stresses that whilst case study has traditionally been considered a ‘soft’ research method it is extremely difficult to do.

### H.4 Strengths and Weaknesses of Case Study

A particular strength of case study is that the detailed report, which is characteristic of this method, makes the findings accessible to people outside the particular field of study. It contains much more information than that obtained from surveys or portrayed by statistical data. However, if the findings of a case study are to have credibility, it is imperative that it is carried out in a scientific manner with all the information available for inspection. Feagin, Orum and Sjoberg (1991:68) contend that:

The case study approach, based on in-depth fieldwork or documentary data, has an integrity of its own.
A frequent criticism of case study research is that it lacks rigour and does not easily allow generalization. Merriam (1988:34) warns that both readers and authors need to be aware of biases that can affect the final report and that there may be discrepancies between what people believe they are doing and what they are actually doing. Yin (2003:xiii) emphasises that “the case study has long been (and continues to be) stereotyped as a weak sibling among social science methods”. It is also regarded “as having insufficient precision (i.e., quantification), objectivity or rigour”.

H.5 Types of Case Study

It has already been mentioned that certain ‘how’ and ‘why’ questions are most suited to case study research, which may be exploratory, explanatory or descriptive:

An exploratory case study (whether based on single or multiple cases) is aimed at defining the questions and hypotheses of a subsequent (not necessarily case) study or at determining the feasibility of the desired research procedures. A descriptive case study presents a complete description of a phenomenon within its context. An explanatory case study presents data bearing on cause-effect relationships – explaining which causes produced which effects. (Yin, 1993:5).

It is the exploratory case study, which may be undertaken in response to a ‘what’ question that “has perhaps given all of case study research its most notorious reputation”. Additionally, case study research may involve single or multiple-case studies; however if a multiple-case study is undertaken, the cases must be selected to either directly replicate each other or be predictably different replications (Yin, 1993:4-5).

Three types of case study outlined by Stake (1995:3) are first intrinsic where the researcher seeks an improved understanding of the case being studied. This case has importance in its own right and the objective is not the building of a theory upon which we can generalize. The second type is instrumental where the case is examined in order to gain insight into an issue or theory. The third type are collective case scenarios,
which are a number of individual studies regarding the same phenomenon, undertaken to enable better theorising and understanding about a larger collection of cases.

Anderson (1998:159) writes of the difficulties involved with trying to generalize from one case, whereas conclusions may often be drawn from multiple cases. This is also endorsed by Yin (2003:39-42, 53) who recommends that, whenever the researcher has a choice, multiple-case studies are generally preferable to single studies. Nevertheless, he also adds that there are situations involving, for example, unique, typical or extreme cases when the single case study is indeed an appropriate method. The MLSC case study (see Chapter X) is an example of this. The choice between single or multiple-case studies is a fundamental distinction and must be made prior to the commencement of data collection.

H.6 The Unit of Analysis

Case study is a systematic and rigorous inquiry into a specific instance, which has been identified by the researcher; this instance is more commonly referred to as the unit of analysis. The unit of analysis is a bounded system and may, for example, be a university, a department within the university or a student. The difference between a specific bounded case and a generality is made clear in an example given by Stake in a text edited by Denzin and Lincoln (2000:436), whereby:

A doctor may be a case - but his doctoring probably lacks the specificity, boundedness, to be called a case.

The unit of analysis must be clearly defined at the commencement of the study and the researcher should enter into the study without any preconceived ideas or bias. It is considered by Feagin, Orum and Sjoberg (1991:32) that defining the proper unit of analysis is a major issue in case study research. This problem is also referred to by Anderson (1998:153-154) with the added comment that inherent in the choice of the case lies some knowledge relating to the topic of interest and, therefore, it is the choice of the case itself which sets the general parameters for the research question and identifies the unit of analysis.
Yin (2003:22-26) gives more detailed guidance into defining the unit of analysis. He explains that once the research questions have been determined, it is necessary to state the study propositions (in earlier texts by Yin, these propositions were referred to as hypotheses), which will direct the researcher to what should actually be investigated within the study. He continues by explaining that the how/why questions are what we are trying to determine, but they do not direct the researcher as to what should be studied. An exploratory case study may not give rise to a study proposition; however, the study design must include a purpose in addition to the criteria by which the study will be judged. On the other hand, in explanatory and descriptive case studies, it is the hypothesis that will determine the unit of analysis and is related to the way in which the initial research questions are defined. Additionally, the start and finish of the study should also be determined by a set time limit as this helps to define the unit of analysis and also limits the amount of data that can be collected and analysed.

Regardless of whether a single-case study or multiple-case studies are undertaken, they may be holistic or embedded. An holistic design is when the unit of analysis is the case under study. An embedded case study arises when there may be more than one unit of analysis; this occurs when attention is also given to sub-units (Yin, 2003:42).

H.7 Research Design

The research design is a formal written document, which follows logical steps from the start to the end of the case study and will inevitably contribute to establishing the validity of the study. Unfortunately, case study designs have not been codified. However, there are five components of the research design that are of importance. These are: “a study’s questions; its propositions (hypotheses), if any; its unit(s) of analysis; the logic linking the data to the propositions; and the criteria for interpreting the findings”. The last two points are the precursors to analysis of the data. Covering these five components will enable the construction of a preliminary theory to begin (Yin, 2003:20-28).

The research design is not cast in stone. If, as a result of data collection, a multiple-case study, which was believed to offer replication, or a single-case study which was
believed to be unique or critical, fails to be so, then it is permissible to modify the initial research design. This modification may involve the selection of different cases but it is not possible to change direction from the original objectives without compromising the rigour with which the case study is conducted (Yin, 2003:55). This order of approach is different to that encountered in some other research methods. For example, Glaser and Strauss (1967:32-34), the founders of grounded theory, stress that theory should not precede the design of a research study, but should be the product of it, being grounded in observation.

According to Adelman, Kemmis and Jenkins (1980:49), a case study may be set up in one of two ways:

1. An issue or hypothesis is given, and a bounded system (the case) is selected as an instance drawn from a class...
2. A bounded system (the case) is given, within which issues are indicated, discovered or studied so that a tolerably full understanding of the case is possible...

The importance of integrating theory into the design of case studies is an area that receives little mention in most research texts, the word ‘theory’ only being encountered in connection with generalization. One exception is Bassey (1999:62) who describes theory-seeking and theory-testing as being two types of case study, which he believes to be the same as the exploratory and explanatory case studies described by Yin. Another is Merriam (1988:13, 55-60) who takes the view that theory permeates the entire process of case study research. Those case studies that are undertaken to test, refine or extend theory use a deductive way of thinking, which explains and predicts phenomenon. In contrast, case studies that are undertaken to build theory, which is more usual in education, use an inductive way of thinking, whereby new concepts emerge from examination of the data that has been collected.

The importance of the development of theory prior to commencement of any data collection is stressed by Yin (2003:28-30). He emphasises that the development of a theoretical framework assists in the research design and quotes Sutton and Straw (1995:378) who describe theoretical propositions as:
A [hypothetical] story about why acts, events, structure and thoughts occur.

In a chapter that is dedicated to case study in educational research Yin (1993:38-39) explains the role of theory as an “a priori explanation of why some educational phenomenon might have occurred the way it did”. Whilst the explanation is causal, the theory then becomes the medium for later generalization.

**H.8 Case Study Protocol**

The case study protocol is a detailed written plan of the research design, covering all the stages to be undertaken; from the reason for doing the research through to the style of the case report. It has already been mentioned that in order to conduct a good case study it is essential that the researcher adopt a rigorous and unbiased approach. It is also imperative that the investigator is not only able to ask relevant questions, but is also able to interpret the answers and be perceptive to subtleties and inconsistencies. There are also ethical considerations, which Bassey (1999:74-75) distinguishes as being respect for democracy, respect for truth and respect for people.

A case study protocol is essential when multiple-case studies are being undertaken. Suggested headings for the protocol include: Introduction, Data Collection, Outline of Case Study Report, Case Study Questions and Evaluation. It is this protocol that increases the reliability of the study and helps the researcher to keep the objectives in view (Yin, 2003:67-71). Additionally, considerations regarding the circumstances of the case, the conduct of the study and the consequence of the research all arise from the planning (Adelman, Kemmis & Jenkins, 1980:52).

The training of the researcher for the case study commences with the definition of the questions and the development of the design, but there are other important issues. These include the case selection, the importance of conducting a pilot study and the investigator to have adequate skills to conduct the study (Yin, 2003:57-81). These issues have been covered in Chapter IV (sections 4.2, 4.3 and 4.4) and also in Chapter I (section 1.4).
H.9 Data Collection and Triangulation

Whilst data for case studies may come from many different sources, Merriam (1988:10) asserts that there are not any particular methods for the collection or analysis of data when undertaking case study. The different sources of data identified by Yin (2003:83) are, “documents, archival records, interviews, direct observation, participant-observation and physical artefacts”.

Checking data across several different sources inevitably results in the likelihood that a case study will be more accurate and convincing. The data collection stage will, without doubt, produce a wealth of material to observe, analyse and cross check; all of which must be meticulously recorded and filed. Van Dalen (1979:295) describes this as the time when:

investigators saturate themselves in the setting and probe in depth to identify the variables that relate to their problem.

When using documents and archival material, care needs to be taken to establish their accuracy. This form of evidence may not be lacking in bias as it may have been written for a different audience and for a different purpose (Yin, 2003:87).

Regarding data for the case study, Anderson (1998:155) writes, “The interview is a prime source of case study data”. Whilst there are many different forms, which an interview may take, the most common classifications are structured, semi-structured and open-ended (Burns, 2000:423). Yin (2003:90-91) refers to them as being open-ended, focused or following the lines of a formal survey.

In addition to the style of interview, another issue is the question of whether to take notes or use recording equipment. The principal consideration is whether the interviewee objects to having the interview recorded. Another factor is the length of time required to transcribe tapes balanced against the accuracy they provide. Yin (2003:92) addresses this issue and takes the view that whether to record an interview or take notes is a matter of personal preference.
Supplementary to the six individual sources of evidence that have been outlined, Yin (2003:97-106) advocates using multiple sources of evidence, creating a case study database and maintaining a chain of evidence (to enable others to follow your research from the initial questions posed to the conclusions reached). He refers to these as being the three principles of data collection, which can help to establish the construct validity and reliability of the evidence. Issues appertaining to validity and reliability of case studies are discussed in Section H.10.

Not only is the use of multiple sources of evidence necessary for triangulation of the data, it is also a major strength of case study as it develops converging lines of inquiry. The need for multiple sources of evidence is also much greater in case study than in other research strategies (Yin, 2003:97-98).

The building of a case study database is a valuable contribution, and an important aspect of data collection, as it will form the foundation for the chain of evidence (Anderson, 1998:157). For all the cases study research described herein, multiple sources of evidence have been obtained, information relating to each case is filed in an individual folder, factual evidence has been entered into a spreadsheet and all the original data is available for inspection. This is in accord with Yin (2003:102) who emphasises that case study notes should be available for inspection.

The chain of evidence, often referred to as the audit trail, links each stage of the study and must, according to Yin (2003:105), contain enough detail to enable an external observer to follow through the study from initial questions to conclusions or in reverse from conclusions back to the initial questions.

**H.10 Validity and Reliability**

In conducting a case study, the investigator must take care not to select only the evidence that supports the conclusion; it is essential that the research is able to demonstrate that the results of the study are both valid and reliable. Another consideration is the effect the researcher may have had on any observations, especially when participant observation is an ingredient of the data collection aspect of the study.
Finally, there must be awareness that the investigator’s own bias may to some extent have a bearing on the interpretation of the data (Chapter I, section 1.5).

For a case study to be valid, the research must be valid and for the work to have any impact it is essential that the findings are trustworthy. The issue of validity arises in both qualitative and quantitative research; however, case studies need to be both externally and internally valid (Wellington, 2000:98). Merriam (1988:166) is of the opinion that internal validity contends with the question of how one’s findings match reality and Anderson (1998:159) takes the view that internal validity in case study is incorporated in the chain of evidence. Yin (2003:34) points out that it is only when undertaking explanatory case studies that there is a need for internal validity, where it is required for establishing a causal link. Merriam (1988:173) describes external validity as the “extent to which the findings of one study can be applied to other situations”. In addition to internal and external validity, Yin (2003:34) also raises the issue of construct validity, which establishes correct operational procedures for the study being undertaken.

Reliability is linked to operations of the study, such as the procedures for the collection of data, whereby; the same results would be obtained if these procedures were to be repeated. The four tests; construct validity, internal validity, external validity and reliability are the criteria for judging the quality of research designs and are relevant to case study (Yin, 2003:33-34).

The measures that have been taken to ensure the validity and reliability of the case study work undertaken herein are included in Appendices A, B, C and F.

Regarding the question of theory that could be tested, or applied at the level of general principles, Ruddock and Hopkins (1985:54) consider that:

Most social science and most history falters here in respect of education. Social science too often produces concepts (jargon) that seem stepping-stones into a lake rather than across a river.
They continue by explaining that if theory at the level of cause and effect is appropriate to educational study, “then it will have to stand the test of the study of cases”.

**H.11 Analysis**

Whilst most texts describe the analysis of case study data as being extremely difficult, very few offer any detailed or constructive help with which to address this difficulty. The process is described by Bassey (1999:83-84) as:

> Fundamentally what it is about is an intellectual struggle with an enormous amount of raw data in order to produce a meaningful and trustworthy conclusion which is supported by a concise account of how it was reached.

Anderson (1998:157-158) likens the process of case study analysis to “walking through a maze”. He identifies four elements of case study analysis; “interpreting your findings whilst in the field, coding and organizing the data into themes and constructs, searching for disproving themes or evidence, and testing alternative interpretations of the data to see if your understanding of the information changes”. He also describes pattern matching, whereby patterns of relationships that have been observed in one situation are predicted in another. “When the two patterns of interaction match, then validity is added to the conclusion”. He also adds:

> There are many routes available, some lead you quickly to the end, others force you to choose one path over another, and some routes lead to a dead end causing you retrace your steps and try again.

Ongoing analysis is important to avoid unfocused and repetitive data; a small number of categories (themes) suggest a level of abstraction whereas a large number of categories are likely to suggest that the analysis has been based on solid description (Merriam, 1988:124,135). Additionally, Guba and Lincoln (1981:95) give four examples of categories that could be developed; the frequency with which something occurs, the appeal to a particular audience, uniqueness, or the revelation of “areas of inquiry not otherwise recognised”.

- 475 -
As strategies and techniques for case study analysis have not been well defined, it is a difficult process. There are three possible strategies and five analytic techniques that may be used. The strategies are: relying on theoretical propositions, setting up a framework based on rival explanations and developing case descriptions. Any of these may be used. The preferred strategy is relying on the theoretical propositions that led to the case study and these are reflected in the questions posed. Rival explanations can be used even if the original theoretical propositions did not include rival hypotheses. The more rival explanations that are addressed or rejected in the analysis, the more confidence can be placed in the findings. The least preferred strategy is developing a case description, which is a framework for organizing the study. Nevertheless, this is useful when difficulties with either of the other two strategies are being experienced (Yin, 2003:109-114). It is Yin’s preferred strategy for analysis that has been used for the case study research in this thesis.

After the strategy has been determined, the five specific analytic techniques suggested by Yin (2003:116-139) are: pattern matching, explanation building, time series analysis, logic models and cross-case synthesis. Pattern matching as referred to earlier, compares one pattern with another. Explanation building is a special form of pattern matching, whereby an explanation about the case is constructed, and from this explanation, analysis of the case study data is then conducted. Times-series analysis is concerned with the match between a trend of data points when compared to one or more of a significant theoretical trend, some rival trend, or any other trend based on an object or a threat to the internal validity. Logic models require a complex chain of events, which may exist over a long period of time. “The events are staged in repeated cause-effect-cause-effect patterns”. Finally, cross-case synthesis (the gathering together of findings from a number of studies) is specifically linked to the analysis of multiple-case studies. This has been used for the multiple-case studies reported in this thesis. For the MLSC single-case study, there are embedded units of analysis (the students who use the centre and the staff who work in it) and cross-case synthesis between these embedded units has been employed.

It is apparent that as analysis progresses, a framework or strategy needs to be developed. This must be undertaken rigorously and data must not be omitted if it does not fit the framework.
The case study report is a descriptive story, which must use plain language, present a clear and realistic interpretation and make recommendations; moreover, it must be interesting to read. One point that is raised by many authors, for example, Yin (2003:143) and Merriam (1988:187) is that prior to writing the report it is important to identify the audience for whom you are writing. A decision must also be made as to the amount of information that it is necessary to include in the report, to enable the reader to follow the logical processes, and what to place in the appendices. A useful reminder from Stake (2000:448) is that:

The purpose of a case report is not to represent the world, but to represent the case.

The report makes connections between the data and conclusions, and as it is a form of scientific writing, any generalisations must be supported by evidence, any inconsistencies must not be ignored and weaknesses in the data must be acknowledged. There is a need to select a focus for the report, which depends not only on the audience but also on the purpose of the study and the level of abstraction. Examples of foci are: a thesis, a theme, or a topic (Bogdan & Biklen, 1982:172-173).

The case report may be structured in many different ways, Bassey (1999:84-89) details several styles, including, structured reporting, narrative reporting, and descriptive reporting. Merriam (1988:200) refers to the styles as particular description, general description or interpretative commentary. The formats cited by Yin (2003:146-149) are: single narrative (to describe and analyse a single case study), multiple narrative (for multiple case studies), which may also include cross-case analysis and results, a series of questions and answers or just cross-case analysis, both of which may be used for either single or multiple-case studies. He also recommends that the style of reporting be selected early in the design of the case study, as this helps to focus attention on the research being undertaken. Nevertheless, the chosen style may be altered if developments in the research make this advisable. Furthermore, Merriam (1988:193) points out that there does not exist a standard format for reporting case study research.
H.13  An Exemplary Study

Unless the case study has been rigorously conducted, logically analysed and meticulously reported, the researcher will be unable to defend the findings and conclusions drawn from the study. It will then fail to make any serious contribution to research. Therefore, it is imperative that the study is as watertight as is possible. Yin (2003:160-165) has determined five characteristics of an exemplary case study:

- The case study must be significant
- The case study must be ‘complete’
- The case study must consider alternative perspectives
- The case study must display sufficient evidence
- The case study must be composed in an engaging manner

For the case study research presented in this thesis, Chapter IV (section 4.6) refers to the issues that have been considered to ensure that this work is of an exemplary nature.

H.14  Conclusion

This section has detailed case study as a research method, from inception to completion and, as it has been shown, it is not easy to do well. To conclude, Anderson (1998:154) reports that:

A case study is difficult to do well, therefore the researcher contemplating a case study should be experienced in all the separate requisite methods. He or she should have a deep understanding of the relevant literature, be flexible, be able to ask good questions, listen, observe and have an inquiring open mind.

All references for this Appendix are included in the references contained in the printed thesis (see pp336-348).