Girls boys and technology: competence confidence and creativity in the primary years

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Girls, boys and technology: competence confidence and creativity in the primary years

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Abstract
The differences between boys' and girls' abilities revealed in technological activities reflect observations in science and mathematics. These differences can affect their progress. This longitudinal action research study has investigated the influence of work with construction sets on pupils' technological achievements throughout the primary years.

In its final report this study provides information on how children's learning of the physical science concepts encountered in design and technology can be developed through construction activities and offers criteria for the assessment of such activities. Teaching strategies and support materials have been developed to structure learning experiences in order to match these criteria.

The gap between boys' and girls' achievements when working with construction sets in the primary years has proved to be extensive and the effects of compensatory experience are complex. Links between evidence of pupils' knowledge and skill in Design and Technology and the development of positive attitudes towards Design and Technology have been investigated. The results have enabled some recommendations to be made for the structuring and organisation of work with construction sets throughout the primary phase.

Background
The Primary Technology Project at University of East Anglia was set up to investigate the potential of construction sets as an aid to Design and Technology teaching in the primary school. Research by the Assessment of Performance Unit (APU) had previously highlighted the disparities in children's leisure experiences of this kind. The APU tests of Science at 11, 13, and 15 years showed that there was an increasing drop in performance in physical science with increasing age. A subsequent analysis of these APU results linked early modelling experience with girls later mathematical and scientific achievement in a way which made the lack of such experience a cause for concern. Further research since then has tended to confirm this link and its effects on option choices at secondary level. For example the recent survey of girls' own opinions by the Engineering Council found that:
...many of the writers felt that when girls arrive at secondary school they lack the pre-understanding of engineering that is often acquired by boys from their hobbies and through toys. That means that they may lack self confidence and be apprehensive about studies in science and technology.

It is important to note that some boys may lack experience of this kind too. A comparison of gender related performance might also contribute insights into factors affecting progress in learning of technology for children of either sex who under-perform in this area.

Unlike much other equipment required for Design and Technology construction sets of various kinds have been familiar features in primary schools for many years. Frequently they were classed as play materials, being used mainly for recreation and reward. When it became apparent that Design and Technology was to form part of the statutory curriculum their role was unclear. There was little relevant research available on their developmental potential for this subject. The importance of finding out about children's existing knowledge of construction sets, as indicated by the APU survey, was supported by the findings of the Children's Learning in
Phase 1: from reception to year 3

It was decided that the project would study one specific intake of pupils over the three years. Their use of construction sets for design and technology would be investigated as they passed through each class in the school. A variety of commonly used construction sets - many already in the school - would be made available on a weekly basis.

Action research methods would be used to collect information, to describe what was achieved by pupils in each class, to identify any gender gaps in technological achievement and to feed this information back to the teachers. Teaching strategies would allow considerable freedom of choice in model making but would try to ensure equal access to materials, support and guidance.

Analysis of the observations, photographs and notes made in the weekly sessions led to the identification of concepts which pupils had incorporated into their models. A list of criteria was drawn up against which models could be assessed. When the project was completed it was possible to condense the criteria identified during each of the three years into one list. [see Table 1]

The list of criteria was used to construct separate working papers for each class. These operationalised the criteria putting them in the form of suggestions for modelling activities. Reference was made to those construction sets which might be used to meet the criteria and examples given of models which could be made. The working papers were tried out for a year and modified accordingly. A list of the models made during that year which could be updated annually was added for information. [see Table 2]

Models made: Animals, things we use (fridges, telephones), terraced houses, radios, play/fairgrounds, waterwheels, bridges, cars, machines to pick things up.

Results of phase 1

When the models made in each year were analysed and the boys' results compared with the girls' it was found that the progress made was sufficient to have considerably narrowed the gap in achievement between the girls' and
Table 1

Criteria for children using construction sets

Make a model
1. Which has a predominately two dimensional structure.
2. Which consists of a three dimensional solid structure.
3. Which consists of a 3D structure with an outside and inside.
4. Which consists of a 3D structure which is subdivided into sections either horizontally or vertically.
5. Which consists of several 3D structures assembled into a complex.
6. Which consists of a 3D structure incorporating movement through use of ready-made moving parts.
7. Which incorporates a lever to move some parts.
8. Which incorporates movement by use of moving parts assembled from basic pieces.
9. Which uses stored energy to power a model.
10. Which incorporates pulley wheels for movement of parts.
11. Which uses gear wheels to transmit movement.
12. Which uses a belt or chain drive to transmit movement.
13. Which uses a drive shaft to transmit movement.
14. Which uses parts to change the speed of movement.
15. Which changes the type of movement from rotary to up and down.
16. Which changes the direction of movement.
17. Which uses switches to control powered models.
18. Which uses a computer to control powered models.

Table 2

Year 2: Working Paper

Suggested activities for children using construction sets. These may be carried out, out of order, and repeated more than once in different models but an attempt will be made to give each child at least one opportunity to try each type of activity. Any appropriate construction sets may be used.

Make a model
1. Which consists of a 3D structure with an inside and outside, a hollow structure or an enclosure [e.g. use wooden bricks or Lego to make a castle].
2. Which consists of a 3D structure which is subdivided into sections either horizontally or vertically [e.g. use bricks or Lego to make a multi-storey car park].
3. Which consists of several 3D structures assembled into a complex [e.g. use bricks or Lego to make a local row of shops].
4. Which consists of a 3D structure incorporating movement through use of ready-made moving parts [e.g. use Lasy or Lego make a wheeled vehicle or a windmill with moving sails].
5. Which incorporates a lever to move some parts [e.g. use Lego to make tip-up truck or Lasy to make an animal with legs which bend].
6. Which incorporates movement by use of moving parts assembled from basic pieces [e.g. axle and wheels for car, set of sails for windmill].
7. Use stored energy to power models [e.g. use clockwork motor to make a bus or battery pack and light bulb to make a shop with lights].
8. Which incorporates parts made into a pulley system [e.g. make a builders hoist to lift bricks or a chair lift to take people up a mountain].
9. Which uses gears to transmit movement [e.g. make a roundabout using gears to turn it].
10. Which uses a belt or chain drive to transmit movement [e.g. use Lego technic to make a caterpillar tracked truck or Lasy and rubber bands to make a big wheel for a fair].
boys' groups. For example, at first the girls had a greater tendency to make static simple models than the boys who made models which were mobile and structurally more complex. [see table 3]

By the end of the third year the girls had increased the range of concepts they used. By then they were using mechanical concepts much more often and including moving parts such as belt drives. The boys had also increased their range in the meantime and used six mechanical concepts more frequently than the girls. Both girls and boys had begun to use switches and controls. The gap between the girls and boys in their familiarity with mechanical and simple electrical concepts had diminished but had not been eliminated. It was decided that the project should continue to see “how long it would take” for the girls to catch up and that monitoring of the use of construction sets by both boys and girls should continue over the next four years.7

Phase 2 : from year 4 to year 7

The middle school study was conducted in a similar way to phase 1. “Friendship grouping” was used to facilitate equal access to the construction sets. The equipment continued to be that which was either in the school already or recommended for children of that age. During year 4 and year 5 half-class lessons provided frequent opportunities for modelling. In years 6 and 7 work with construction sets and Lego SEQ minicomputers was offered to groups of four to six pupils at a time in rotation throughout the year.

At the end of year 4 information collected on the concepts incorporated into the models that year showed that eight out of the ten concepts had been put into practice with equal or greater facility by the girls’ group. However it was noticeable that the range of models made by the boys’ group was greater with only four designs being repeated. The girls' models showed a much higher incidence of repeated designs. It was decided therefore that the variety of models made by the two groups should be compared as well as the concepts they incorporated. Evidence of the variety of models each group made provided a measure of the confidence each group felt in the ability of individuals to branch out on their own and not repeat what others had made.

This finding also prompted scrutiny of the extent to which the models were original. Some were copied from pictures or diagrams, others were extensively modified and some were entirely constructed from the child’s own idea. It was decided that those which were modified or wholly original would be

### Table 3: Comparison of % difference between concepts as incorporated into models made by the boys and girls

<table>
<thead>
<tr>
<th>Concepts incorporated</th>
<th>R/Yr1 (1988/89) % difference</th>
<th>R/Yr1 (1988/89) % difference</th>
<th>Yr2/3 (1990/91) % difference</th>
<th>Yr2/3 (1990/91) % difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D model</td>
<td>+5%</td>
<td>Stable structure</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>3D model</td>
<td>+6%</td>
<td>Wheels</td>
<td>-11%</td>
<td></td>
</tr>
<tr>
<td>Hollow model</td>
<td>+13%</td>
<td>Pulley</td>
<td>-2%</td>
<td></td>
</tr>
<tr>
<td>Subdivided model</td>
<td>-1%</td>
<td>Gears</td>
<td>-10%</td>
<td></td>
</tr>
<tr>
<td>Model complex</td>
<td>0%</td>
<td>Levers</td>
<td>+17%</td>
<td></td>
</tr>
<tr>
<td>Ready made moving parts</td>
<td>0%</td>
<td>Belt drive</td>
<td>+8%</td>
<td></td>
</tr>
<tr>
<td>Self assembled</td>
<td>-3%</td>
<td>Chain drive</td>
<td>-12%</td>
<td></td>
</tr>
<tr>
<td>Battery powered</td>
<td>-2%</td>
<td>Drive shaft</td>
<td>-9%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motors</td>
<td>-8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Switches</td>
<td>+1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control panel</td>
<td>+3%</td>
<td></td>
</tr>
</tbody>
</table>

+=more girls than boys used the concept in their models
-=more boys than girls used the concept in their models
distinguished from those which were simply copied. The number of original or modified designs each group produced could be compared to those simply copied as an indication of the level of creativity in each group.

**Results of Phase 2**

1. **Concepts and Competence**

   In an overall view of all four years the findings show that the concepts most successfully implemented by the girls and boys groups were markedly different. In the first two years the girls continued to improve their competence in implementing mechanical concepts but in years 6 and 7 became extensively overtaken by the boys in this area. [see table 4]

2. **Variety and Confidence**

   When the number of different types of model made by each group was compared it could be seen that the girls' and boys' achievements had become more similar over the four years. By year 7 the girls were confident enough to make a range of models of greater variety than the boys. [see table 5]

**Table 4**: Summary of the % difference between boys' and girls' use of science concepts in models made with construction sets

<table>
<thead>
<tr>
<th>Concepts successfully implemented</th>
<th>% difference in frequency of use</th>
<th>Yr4</th>
<th>Yr5</th>
<th>Yr6</th>
<th>Yr7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulleys/cranks/cams</td>
<td>+10 +64 NR NR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable frame/chassis</td>
<td>+6 +12 -16 -23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spindle/axle/drive shaft</td>
<td>+1 +10 -38 -31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rollers/wheels</td>
<td>+2 +9 -30 -21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belt/chain drives</td>
<td>+29 +23 -19 -30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gears</td>
<td>NR +23 -30 -7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levers</td>
<td>-45 -5 -10 -24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric motors</td>
<td>NR -29 -20 -39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric switching</td>
<td>NR -21 -1 -1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric lights/buzzers</td>
<td>NR -29 +17 +10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer control [switching on/off]</td>
<td>NR NR +7 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer control [programming a sequence]</td>
<td>NR NR NR +3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NR = no record of use of this concept
+ = more girls than boys used the concept in their models
- = more boys than girls used the concept in their models

The introduction of electrical and electronic materials (LegoTechnic 2 and TEKO motorised sets) in Year 5 saw them initially used more by the boys than the girls. This gradually changed through years 6 and 7 when these concepts increasingly appeared more often in the girls' models with the exception of electric motors.

**Table 5**: Summary of the variety and originality of the models made by boys and girls using construction sets

<table>
<thead>
<tr>
<th>Variety: the number of different types/the number of models made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls models</td>
</tr>
<tr>
<td>No. of types/no. of models</td>
</tr>
<tr>
<td>Year4</td>
</tr>
<tr>
<td>Year5</td>
</tr>
<tr>
<td>Year6</td>
</tr>
<tr>
<td>Year7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Originality: the number of original or modified designs/number of models made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls models</td>
</tr>
<tr>
<td>No. of originals/no. of models</td>
</tr>
<tr>
<td>Year4</td>
</tr>
<tr>
<td>Year5</td>
</tr>
<tr>
<td>Year6</td>
</tr>
<tr>
<td>Year7</td>
</tr>
</tbody>
</table>

3. **Originality and Creativity**

Over the four years the originality of the models made by the two groups was consistently diverse. Despite the presence of some talented individuals the girls, as a group, were less creative throughout than the boys, making fewer original models, or models which were the result of modifying an existing design.

**Some Implications of the Results.**

**Phase 1**

In the first school phase, all the children made good progress, their competence in conceptual implementation increasing in each year. The girls, having less initial background and a continuing deficit of relevant leisure experience, nevertheless made strong conceptual gains. The range of physical
science concepts they used in their models widened and they excelled in their use of some mechanical concepts such as levers and belt drives.

These three years offered frequent opportunities for model making. Teachers ensured equal access to materials by rotating equipment rather than allowing open choice. The structured guidance for teachers offered by the working papers helped to show what to look for in children’s models and what might be done to extend their work.

Phase 2
1. Conceptual Competence

In the middle school the pattern of concept implementation showed that the boys as a group continued to develop and expand their competence in mechanical concepts. Increasingly they extended their scope by using electrical motors. In contrast, after the first two years the girls did not go on to build more complex machinery. They tended to move away from making mechanical models to explore the lights, buzzers and switches with the minicomputer controls.

The questions arising from these observations are twofold. How can the boys’ competence in mechanical concepts be extended to increase their use of controls and programming? How can the girls’ early competence with mechanical concepts be developed and linked to their growing competence with electrical and electronic concepts?

2. Variety and Confidence

The experiences offered and the equal access to the construction set materials which was maintained throughout the study have been effective in building girls’ confidence. The use of friendship grouping and the specific management of materials to ensure access seem to have enabled them to branch out and increase the variety of models made.

However, the instability of these results and the fragility of the gains indicates a need for more attention to this aspect in primary schooling. It also suggests this attention needs to be continued into secondary schooling if girls’ confidence is to be maintained.

3. Originality and Creativity

The pattern over the four years, when girls and boys groups are compared is one of slow progress in the girls group but of stronger development in the boys group. The girls increases in competence and confidence previously described have been accompanied by a small increase in their creativity. The implication of this finding is that girls need this ability to be given a higher profile throughout the primary years. It suggests that support on this front will also be necessary during secondary schooling.

References
4. SPACE Science Process And Concept Exploration Project (1990-92) University of Liverpool Press.