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Engineering design projects for schools

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Abstract
The Engineering Council makes presentations to schools to increase the awareness of Engineering, in all its forms, to students largely in the age range 11 to 18.

This paper addresses particularly the use of Engineering Design projects of a fully participatory nature and shows through several examples how such projects can bring out the innovative skills of students.

Design projects are preferred in which there is more than one valid answer; there are indications that the correlation between students with a high rate of learning in a conventional sense and those with good innovative skills is not good.

Bearing in mind the urgent need in engineering and industry for people with well developed innovative capabilities this preliminary work calls for the development of further engineering projects aiming at participatory classroom sessions to explore further ways of identifying those students with design and innovative talents, preferably at an early age.

This paper deals with six design projects and indicates the objectives and philosophy of each project with the 'feedback' from the presentations obtained to date.

The projects are detailed in the Appendix.

Projects 1 and 2
Projects 1 and 2 are similar in that they call for some technical skills and appreciation but principally require imagination and innovative capability.

Briefly the student is asked to work in groups of three or more and produce sketches of an emergency shelter to be used under very difficult conditions. See Appendix Projects 1 and 2.

An underlying philosophy is to test and encourage students to work in small groups as a team under pressure. The time of the session may be as little as an hour or as much as 2 or 3 hours. One hour is a very short time for obtaining a workable design but even so good responses have been made. One hour fits easily into the school curriculum but, particularly with Project 2, extended periods or 'follow up' sessions in which the students produce models works very well indeed.

The best results have been obtained on Project 1 when longer periods of up to three hours are allowed giving an ogival design in which the covering material and other life support materials are encased in the folded section.

Students curiously misinterpreted the given situation from time to time; one group even made provision for flooding!

Other groups produced designs based on a conventional box type structure simulating a 'house' and quite frequently the folded structure was too large to be manhandled out of the aircraft.

Triangular based structures have been common but an interesting one was essentially a tetrahedron.

These projects inevitably succeeded in stimulating the students to enthusiastic activity.

Older students, particularly those with design experience, tended to perform best but a group of 'gifted children' in the age range seven to eleven performed very well.

These designs achieved all the objectives and any outstanding groups came rapidly to the fore and were easily identified particularly if they worked as an effective team from the outset.

Project 3
Project 3 promotes the phrase "Without engineering there is no civilization".

This project has appealed to school managers that do not wish students to be drawn into altruistic discussions but prefer them to concentrate on specific concepts.
Jackson

A public school in particular seems to have promoted a 'perfectionist' approach at the time of the presentation; the students did not easily slip into a 'sketching mode' but, perhaps too painfully, used set squares and rulers. The project has been generally well carried out but the element of challenge seems to be less marked.

There is surely a need to relate to a human need; although its exists in this project in that the design of the Sydney Opera House was seen to call for an innovative and aesthetic concept, students were less easily motivated to the same level of enthusiasm than for the following Project 4.

Project 4

Project 4 is designed to stretch the innovative skills of the students as far as possible, to develop a sense of urgency and precision and, because there are potentially several answers, some better than others, to test the ingenuity of the students and bring out any natural engineering capabilities.

There is also scope for students to see the project as a management or, even a 'military studies' exercise.

'High achiever' students tended to recognise that a suspension bridge using the trees on the Indian burial ground as a basis for building the towers was a possible answer. No thought was given however to the probable result of provoking attacks by Indians as a result of this action.

There is some room for a mathematical approach.

For example, if the saplings average 25 feet in height the top five feet could be removed as tapering to too small a cross section. If the average base diameter is 6 inches it would be reasonable to calculate the volume and weight of the trees used and their strength under load.

The height of the towers compared with steel towers and the nature of the catenary for rope compared with a chain or steel rope would also be worth considering.

Strength to weight considerations are naturally important and the significance of 'Young's Modulus' when dealing with materials of different tensile strengths is an important factor.

'Lower achievers' however did, at times show particular ingenuity; one group conceived the idea of a continuous pulley system, taking the components of the wagons and using slings for the horses to transport the train to the other side and reassembling.

The germ of an idea of using a 'rope gravity slide' began to form with some 'lower achiever' students but it will be interesting to present this project to other groups of students.

The use of the Maslow diagram, was helpful in some cases and further work to develop projects which easily fit into this philosophy would be clearly a profitable approach.

Project 5

Simpler concepts, such as Project 5, have a place in the scheme calling for spatial designs but also materials science skills.

Project 6

Finally Project 6 concerns the development and production of careers events boards which have now been made and used on a number of occasions with great success. Eight 'A' level students at Weston Favell School in Northampton carried out the work which called for a great deal of team coordination and management skill.

Conclusions

All of the projects have involved team work and, very importantly, presentations by the groups, mostly of 3 to 6 students, at plenary session. These projects have been very successful and inevitably enjoyed by the students. In fact throughout the numerous presentations made there have been no failures and complete cooperation.

The next step must be to involve the Mathematics, Chemistry and Physics courses in line with National Curriculum and projects of this type have already been produced and initial presentations made.

Apart from a brief introduction, an engineer dealing with one of these projects maintains a relatively low profile except at the end of the session when there is an opportunity to discuss the results of some or all of the students work in open session.

The engineer therefore acts wholly in a managing and coordinating role.

In all of these projects the students are expected to consider that materials and implements, among other things, are available on a 'good sense' basis in
line with the particular project.

Finally the teaching staff make whatever input is appropriate within the National Curriculum both at the time of the project or by amplification/development at a later date.

Appendix
Project 1
Situation
About a million people are starving and dying of heat exposure and thirst in a North African desert and scrub land; the temperature is very high during the day and near to freezing at night.

Money, not unlimited, is available to provide these people with shelter.

Potential remedy
Time is a vital factor and supplies can only be made from the air employing ‘Hercules’ transport aircraft.

Materials available at short notice are as follows:-

1. Heavy plastic sheeting  this may be:
   (a) Transparent
   (b) White (opaque)
   (c) Black (opaque)
   (d) Silvered; reflecting.

2. Tubes  1/4" to 2" outside diameter in:
   (a) Steel.
   (b) Aluminium base alloy.

3. The wall thickness of the tubing may be:
   (a) 1 mm
   (b) 2 mm
   (c) 3 mm
   (d) 4 mm

3. Several joining systems for the tubing are possible, but new ideas are invited. The tube ends may be modified in the UK with a range of fittings available for different designs - however time is very important.

Suggested tube end fittings are:
(a) U shaped lug and spigot with pin - welded construction.
(b) Two, three and fourway couplers with clamping screws at standard angles e.g. 90°, 45°, 30° and, of course, 180°
(c) As (b) but some screw threaded - the ends of the tubes may be threaded in the UK.
(d) Especially designed multiangled three dimensional couplers may be cast but as time is critical, simplicity as far as reasonable possible is desirable.

Design problem
Bearing in mind that the area can only be supplied from the air but that there is no landing strip, design a shelter so that the components can be packaged and dropped from the air either by parachute or at low level out of the rear of the aircraft.

The shelter must be easily erected, and as far as reasonably possible, be suitable for day and night time habitation, and must be sufficiently rigid to withstand wind pressure and sandstorms of up to 30 miles per hour.

Securing the plastic sheeting to any frame you design will require a particular technique such as steel clips; these also must be designed. Other securing methods employing relatively minor quantities of other materials may be used.

The plastic sheeting may be precut in the UK.

Session procedure
It is suggested that the session splits up into small groupsto form ‘companies’ to tender by presenting the designs.

Each group will be allowed five questions with the answer given in open forum.

Also each group will elect a leader to present it’s findings, summarised as a largely verbal presentation in two or three minutes to the full session.

Project 2
Situation
In Northern Iraq men, women and children of all ages are trapped on the peaks of mountainous country with the Turkish army before them and the Iraqi army behind.

Hercules air transport systems are dropping food, blankets, plastic sheeting and medicine, among other things, by parachute.
There is no shelter to maximise the value of these supplies.

**Design exercise**

Bearing in mind the urgency, the limitations regarding transport, the shortage of technical skills, the deteriorating health of the people, the bare and variable terrain, the weather which may be freezing or wet, to give mud and flood, design an easily erectable shelter from, it is suggested, some of the following materials:-

1. Plastic sheeting, transparent, black or silvered.
2. Light weight steel tubing. Give your own dimensions.
3. Aluminium tubing. Give your own dimensions.
4. Design couplers or fittings to secure the tubes to one another.
5. Ropes steel, nylon or other. Give your own dimensions.
6. Design methods of securing the plastic sheeting.
7. Inflatable ‘rubber’ units using light weight compressed air attachment for inflation purposes.

Where possible existing designs would be helpful but not essential.

8. Incorporate any other design ideas into your structure as you see fit.

**Project**

Employing coloured felt pens and paper, approximately 23"x16", sketch your impressions of a building based on a circle and sphere as distinct from a square and rectangle. The building may be of any type such as a domestic house, a school, skyscraper, office building, library etc.

**Procedure**

Form groups of 4 to 6 as convenient, each group should work as a team. Select one or two spokeswomen or spokesman and give a two or three minute verbal presentation to the whole group and with the help of your drawings discuss how you formed your ideas and your overall objective. Try and answer the following questions in a few words.

1. Do you think the eskimo’s igloo was developed accidentally or was it based on the available material?
2. Do you think the African beehive hut made from available materials would have been more functional if designed as a cube?
3. Is the modern form of western architecture based on square and rectangular form an advancement on historical methods or a regression?

**Project 3**

Design project - Engineering and Art

“Without engineering there is no civilization”.

**Introduction**

“A classic engineering approach aims at: practicality, simplicity, adequacy and cost”. (RSA Journal June ’89 p429). Architecture, however, must take the above into consideration but aesthetic factors are very variable both in period, technique and geography.

The Sydney Opera House has combined both advanced engineering techniques and a new art form. The art form is based upon sections of a sphere. (RSA Journal June ’89 p433).

**Project 4**

‘Bridge design’

**Situation**

A wagon train of 150 vehicles carrying 532 people is crossing North America. The train has been halted at a 230 ft wide ravine stretching for many miles North and South. Scouts have returned after many hours reporting that they can find no way round or across the ravine which is some 200 ft deep.

Due to the loss in crossing the river of some wagons, attacks by Indians, and a ‘twister’, there are about fifty injured men, women and children in the train. Food is running short due to delays related to, among other things, an incompetent guide, and further attacks by Indians are expected.

The weather is hot and dry and the terrain is arid. Nearby however is a group of some several hundred saplings fed by an underground spring in which the water is siphoned to the surface to a variable degree but still allowing the trees to survive, if not to thrive. The trees are thought to be on part of an Indian burial mound.

The wagon train contains about 1500 ft of 3/4"
diameter rope, and is largely made up of an Eastern seaboard colony of rope makers, put out of business due to disagreements on religious grounds.

They had hoped to sell some of the rope enroute but only a few hundred feet have been sold.

Design exercise
Bearing in mind that the average height of the trees is about 25 feet with an average trunk diameter of 3", design on c.A2 paper using black felt tipped pen, a bridge to cross the ravine to carry the wagon train to safety, and allowing their progress westward to continue.

Procedure
Form groups of 3 and, working as a team, produce a notional design which will solve the problem, and use your felt tip pens sketches to explain your answer at a plenary session over about five minutes.

Project 5
Environmental design
Situation
A grassed triangular area with houses on all three boundaries and measuring 150 metres by 100 metres by 80 metres requires to be served by metalled paths serving an exit from a location in the middle of one side (100 metre side) and exits from one corner at the end of the 100 metre side, and the third remote corner.

Design exercise
Bearing in mind the need to retain a substantial grassed area, design on A2 or larger paper, a path system to fit, in an attractive and functional way, the above situation.

Draw also a cross section of the path with hard core and/or sand or any other material as a foundation to the path surface, which will support the path against subsidence, weathering or any other hazard which seems appropriate. Consider particularly that servicing and repair costs should be minimised.

The path surface and dimensions should also be considered and included in your drawings. Add any foliage which you think will enhance your design.

Procedure
Form groups of 3 and, working as a team, produce notional designs in felt tipped pens and present your answer at plenary session over about five minutes.

Project 6
Engineering careers
Introduction
This project is designed to raise the awareness of students as to the potential of an engineering career at levels appropriate to their capacity and capabilities.

Schools careers events indicate that a complementary approach for Northamptonshire would be to design and build a display showing a map of the county with the engineering industries and activities, both primary and secondary, together with the relevant engineering education facilities either on the map or suitably coded.

Design brief
The following broad requirements should be used to design a display:

1. The display must be portable in that it can be packaged and carried in, for example, a medium sized ‘hatch back’ private car and that it can be loaded and unloaded and carried and assembled by one person.

2. The display must be reasonably robust in that it could sustain about 30 events without requiring substantial repair.

3. The display should stimulate parents and students into appreciating the potential employment prospects in the wide range of engineering activities in the county, together with the engineering education support facility with particular, but not exclusive, reference to ‘day release’ programmes.

4. The display should indicate the levels of education required by different manufacturing industries with, if possible, an ‘updating’ facility. It is even more important that students should perceive engineering as an activity which employment is available over a range of educational attainment levels and that work for the lower levels of attainment is readily available.

5. The display should incorporate ‘eye catching logos’ of the many engineering units and prospects on offer which are designed to hold the attention of the students and parents and lead them into making further enquiries; the routes for such enquiries to be made should be clear and uncomplicated.
6 The display should make it possible for students and parents, at least notionally, to appreciate the distances that would need to be travelled and the public transport available for a young person to work and attend an evening/ or day release course so that he or she does not become committed to an unduly long working and learning day.

7 The display should include, either directly or by ‘handout’ facilities, the Engineering Council Institutes and Institutions and affiliated societies which make up the Engineering Council professional organisations.

8. Whilst the display would be central to Northamptonshire, the outside boundary region, engineering industry and engineering educational activities should be included so that a student near to the Northamptonshire county boundary can appreciate the travelling feasibility limits and thereby employment potential available within, reasonable distances from home.

9 The display must include in summarised form the engineering qualification scene without promoting unduly an elitist image as it is important to encourage students over a wide range of capabilities and talents including hand to mind craft skills.