Developing an understanding of structures: experiences from primary teacher education

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Abstract

There is a significant body of research into the notion that learners hold ideas which may conflict with "scientific" explanations of perceived reality. This domain of research into "misconceptions" is extensive and often portrayed in terms of children's learning. Of course, adults too bring their own agenda to learning situations.

This paper is focused on some of the ideas that adults, in this case student teachers, may hold in relation to force and its relationship with structures.

There is a clear link with school practice since many of the outcomes of designing and making activity in primary schools feature a product with some structural dimension.

Student teachers were introduced to a problem solving situation focused on a simple bridge-building task, using limited materials. The use of limited materials had a direct effect in terms of guiding participants towards a variety of structural solutions. Outcomes from this practical engagement suggested that some part-formed ideas were imported into the new learning situation.

Within the paper, comparisons are drawn between student ideas on structural strength and evidence from the wider domain of other research findings into misconceptions, such as those involving children's beliefs.

Questions are raised regarding the relationship Design and Technology has with other curriculum areas, notably science.

Keywords: primary, structures, teacher training, misconceptions, problem-solving, force

Knowledge, understanding and teachers

Teacher background knowledge and understanding (Bennett *et al*, 1994) is a significant issue within initial training and in-service teacher education. The matter is in many ways an intense one in curriculum areas such as science and technology. Here, teacher confidence and perceptions of a relevant knowledge base (Holroyd and Harlen, 1996; Kruger *et al*, 1990) and the sheer pace of change in our technological and scientific environment (Rannikmäe, 1998; McGrath, 1999), serve to challenge all existing and intending teachers.

This paper is focused upon aspects of knowledge and understanding that primary teachers may require in order to teach specific aspects of design and technology with confidence and accuracy. The paper further attempts to determine to what extent those who aspire to become teachers are aware of the role of certain scientific concepts in underpinning aspects of Design and Technology activity. Finally the paper then raises questions about the nature of the Design and Technology curriculum itself and the relationship it has with other areas of knowledge, understanding and experience.

Professional and conceptual background

Design and Technology may be seen as having a considerable body of knowledge with which skills interact and thus may give rise to product outcomes. Within the National Curriculum of England and Wales (DFE, 1995), this knowledge is to be found broadly under titles such as “materials and components”, “control”, “mechanisms” and “structures”.

The knowledge-based dimension of this article is focused on structures. Structures are necessarily encountered in a vast array of children’s activity in designing and making. Activities involving the arrangement of materials so that, broadly speaking, they retain their shape when subjected to forces, will have a structural dimension. This applies as much to the humble greetings card as it does to the baking of bread or the building of a tower with a construction kit. A recent publication of a guidance scheme of work by the Qualifications and Curriculum Authority (QCA/ DfEE, 1998) underpins the relevance of structures within the Design and Technology curriculum. Within this scheme, nine out of the range of twenty four classroom planning units feature aspects of structures as the main or shared focal point.

Concern for teacher understanding in the area of structures has become evident with the publication of formal teacher education and self-study materials by higher education and UK government agencies (Kruger *et al,* 1991; NCC, 1992).

Clearly, some degree of teacher background knowledge *beyond* the working level of children is seen as desirable.

Recent changes in the requirements for the qualification of teachers in England and Wales have further underpinned the subject-specific deepening of teacher knowledge. All student teachers in England and Wales now have to comply with certain specified “Standards” regarding background knowledge in core subject areas if they are to gain qualified teacher status. The government-specified Standards (DfEE, 1998) in science require that trainees for primary school teaching should:

> “...identify how the different areas of science relate to each other (unifying principles and concepts), so that they can make conceptual links across the subject, present pupils with a coherent perspective of the subject matter taught and ensure progression in pupil’s learning.” (p 77)

This is a significant demand on students, for it clearly is not sufficient to have a knowledge of say, forces or energy, but an understanding of the *interaction* of these underlying principles. Teacher understanding specific to Design and Technology has been highlighted by the UK Teacher Training Agency (TTA, 1998) with the publication of self-assessment texts intended to provide diagnostic feedback for serving teachers.

Work embracing structures can be seen has having twin purposes in the assembling of knowledge and understanding. It may serve to combine knowledge and experience of the *properties of materials* with *an understanding of forces acting on the materials, or arrangements of them.*

At a classroom level, when children are engaged in designing and making activity in producing greetings cards for example, then they are using a sheet material which can be shaped so that it is able to offer resistance to certain forces. As a consequence, the card can maintain its shape for presentation purposes. The act of putting a crease or bend in a piece of sheet material is significant and the rationale behind this action may be based on the notion that “bends make certain things stiffer or stronger”. In the light of experiences such as this, questioning and observation of episodes of student teachers has provided insights into the learning process.

Problem-solving within a context for learning about “structures”

Subjects providing evidence for this study were drawn from a teacher education background engaged in the first year of a B.A. Qualified Teacher Status (BA QTS) course.

The overwhelming majority were female with just over half aged under twenty one years, and the remainder classified as “mature students”.

These student teachers were exposed to a problem solving setting which was derived from the contextual basis of a popular children's story entitled "Three Billy Goats Gruff".

Student teachers generally prefer *some* obvious classroom link to any task, even if it is clearly stated that the objective is concerned with increasing their own personal stock of knowledge and understanding. The problem-solving task thus had dual impact as a means of demonstrating that structures can be introduced at the level of children by an appropriate context, and of course, the main theme of highlighting and later challenging uncertainties the student teachers might themselves hold.

To provide sufficient challenge at an adult level, students were required to work to a specification relating to a task requiring them to design and make a structure across a 40 cm gap so that it could be traversed by a specified vehicle and support a mass of 50g. Only sheets of A4 paper and paper clips could be used. Economic specifications were added so that materials were attributed nominal values and a budget set for the complete structure.

Outcomes of student problem solving activity

In terms of products, the following outcomes could be identified.

Outcome one – "Tube solutions"

Tubular structures were devised through which the specified vehicle could travel or by

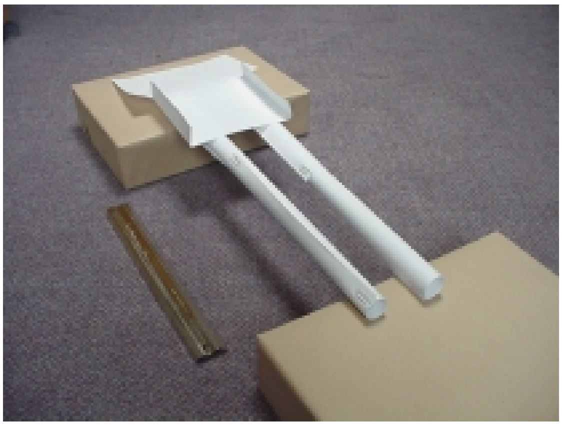

Figure 1 Example of tubular solution. Part of decking removed to show stuctural arrangement

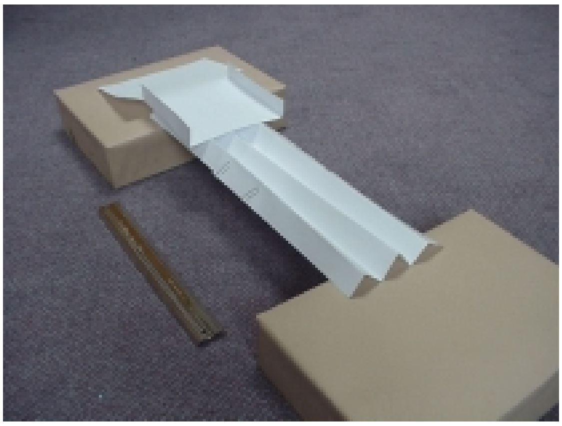

Figure 2 A "concertina solution". Folds aligned with long axis of structure. Part of decking removed to show structural arrangement

arranging a pair or more of tubes disposed longitudinally to the long axis of the bridge upon which decking was laid. Sometimes students made tubular members with a triangular cross-section rather than a circular one.

Outcome two – "Concertina solutions"

Students arrived at this solution by creating multiple concertina-like folds. Sometimes the concertina folds were arranged so they were transverse to the long axis of the bridge. These folds were often incorporated as a core to a "sandwich" with paper decking above and below. This arrangement had inherent weaknesses. Failure to achieve a solution with this first design led to a second concertina solution in which the folds were arranged *longitudinally* to the alignment of the bridge. Entry ramps provided vehicular access to the structure which was necessarily raised to accommodate the thickness of folds.

Outcome three – "U" shaped (cross-section) structural solutions.

Here, vertical slab-like arrangements of paper offered a means of simultaneously retaining the crossing vehicle and providing resistance to stress. Of all the constructions attempted, the "U" shaped variant was the simplest and strongest. In design terms, it was instructive to watch the shift in thinking that sent students toward the U-shaped solution. Designs comprised of some form of decking set upon concertina or tubular elements often had

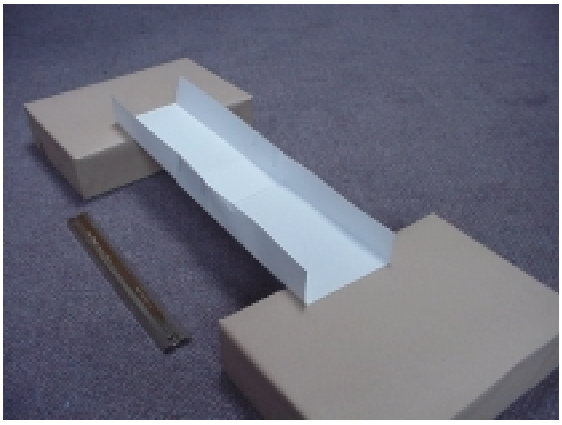

Figure 3 A “U” beam solution

pieces of paper with edges folded upwards to retain the vehicle in the act of crossing the structure. Some students experimented with this additional vehicle-retaining structure to the extent that they discarded the underlying structure of concertina pieces or tubes and simply explored the decking on its own as a replacement structural element.

Student ideas on the role of forces

Students questioned about the constructional techniques employed in the problem-solving setting invariably focused on the terms such as “strong” and “reinforce” when describing and justifying arrangements of materials. As has been indicated earlier in this account, changing the shape of materials – perhaps by folding or bending – was seen as a way of making a “weak” material such as a sheet of paper into a “strong” one. There are a number of issues that arise here.

First issue: what is meant by “strong” ?

Most students did not readily articulate a link between the terms “strong” and “force”. A survey of a sample of student teachers within the BA QTS course (n=40) was carried out. Subjects who were engaged in the bridge problem-solving activity were asked to record their definition of “strong”.

Analysis of the definitions showed that of the key words used to help define “strong”, the word used most frequently was “weight” (19 incidences). Far less popular were the terms “support” and “force” with seven incidences each. In some cases the terms “strong” as well as “support” were used together in definitions. Trailing well behind these terms were key terms such as “durable”, “power” and “energy” with less than three incidences each.

Clearly activity within the context itself, with 50g masses to load onto the structures to meet specifications, was instrumental in guiding the subjects to the weight-derived definitions.

Second issue: what is meant by “weak”?

The second issue concerns student notions of paper as a “weak” material. Students had a tendency to justify their structural arrangements in terms of giving strength to the “weak” paper by actions such as folding or bending. The presumption of weakness in paper is perhaps directly related to an inadequate linking of the concept of strength to ideas on force. If strength is related to force, and if force is simply expressed in terms of pushes and pulls, then a “strong” substance – or structurally devised arrangement of that substance – is one that can offer resistance to various forces.

Moreover, resistance to force can be recognised in the effects of pushes and pulls. Some “strong” substances, like the specially shaped wedge-like blocks lining a stone arch, can offer very considerable resistance to pushing forces. Sheets of paper, however, offer little resistance to pushing forces applied at each end. Some “strong” substances can offer considerable resistance to pulling forces and sheets of paper can certainly do this. Of course, all these terms are relative. Sheets of paper offer considerably more resistance to pulling (extension) forces that they do to pushing (compression) forces.

Analysis and review of findings.

Research suggests that children and adults construct their own ideas about natural phenomena and that these ideas are often different from a wider domain of shared, evidence-based understanding (Driver *et al,* 1985; Osborne and Freyberg, 1985).

A perception within what may be termed a constructivist view of learning, is that appropriate teaching may elicit responses that will expose misconceptions, provide experiences to challenge them and so promote conceptual shift towards the gaining of accurate knowledge.

The notion of "strength" is central to the understanding of structures. Strength concerns resistance to forces and amongst those applied in a structural setting are reaction forces.

Research evidence collected for the primary SPACE research reports (Russell *et al,* 1998) suggests that children do not readily articulate ideas on "reaction forces" – that is they do not appear to recognise that forces act in pairs and that, as a consequence of a force acting upon a structure, the structure will react in opposition to the applied force. In terms of progression in teaching, Simon *et al* (1994) note that

> "Only when more than one force is recognized can thinking about equilibrium start" (p 277)

These ideas add further detail to the notion of "strength" since children may have only a part-formed idea of balanced forces and the way that a structure, or indeed material may "push back" against a force in order to maintain equilibrium and established morphological integrity.

If children continue to carry this part-formed idea, then it is reasonable to work on the basis that without further modification of this view, then it will persists with adults. It seems probable that this notion of objects "pushing back" as a reaction to a force is as counter intuitive to adults as it is to children, and indeed the evidence of Minstrell (1982) supports this view with a study of high school physics students of whom only half suggested that a table might "push back" on an overlying book.

Student teachers then, may carry a range of misconceptions into and beyond their training environments and thus indeed into the primary classroom.

It would seem that the sample of students reviewed in this study carried elements of part-formed knowledge into their problem-solving setting. This part-formed knowledge may have been carried over from experiences such as working with paper (to achieve folds to stiffen it and make it "strong") and pre-existing ideas on the nature of bridges – based perhaps more on what they looked like, than what they did. These experiences were incorporated into the new learning situation to produce physical outcomes – such as the bridges themselves, but also a deeper experience which yielded structural solutions based on corrugations, pipes and U-beams as means of resisting various forces, *even if the students were not sure what forces were operating and where or how they were acting.*

Beyond simplistic qualitative definitions, a measure of strength of course is the modulus, this being stress divided by strain. Stress is a measure of the force (in the bridge context the "load") applied per unit area, whilst strain is a ratio of deformation calculated by dividing the extension (due to stress) by the original size. In other words, the strength of a structure can be quantified by measuring the changes it undergoes when forces are applied.

Students were able to achieve stress reduction by increasing the area over which a given force could act via corrugations, tubes and U-beams, seemingly as an intuitive response to a structural problem.

Discussions and conclusions

Within the bridge-based project, whilst trainee teachers were immersed in an environment which involved scientific and technological ideas, it seems to be the case that they did not formally acknowledge the link to science. The relatively low incidence of the use of the term "force" in discussions is a key pointer in this respect. Instead, terms such as "strength" and "reinforce" were employed, and seemingly intuitive interpretations of these led to solutions, but with little apparent consideration given to underlying concepts.

A broadly similar study with the modelling of bridge-like structures concerning year 9 pupils in Australia (Venville *et al*, 1999) supports this view of a lack of consideration of links to science. A majority of students in this study did not perceive their scientific knowledge as being useful for problem-solving. An explanation for this lack of recognition of the science aspects of the technology project is that:

> "... students saw science more as a content oriented subject rather than a skill or a process oriented subject" (p 45)

If science is seen as "different", then scientific ideas embedded in broader fields of experience may be seen to be different or irrelevant – or perhaps may even fail to surface as ideas at all.

The construction task at the core of this study was offered in a problem-soving context and students were free to develop and discuss their own ideas so that their thinking could be explored. If this experience had not been employed simply as a research procedure and utilised instead a sequence for challenging misconceptions, then learning outcomes would have been different. Within a constructivist framework such as that offered by Ollerenshaw and Ritchie (1993), the initial sequence of "orientation" and "elicitation" would have provided a contextual setting and exploration of prior thinking. An "intervention" phase would have allowed the all-important re-structuring of ideas relating to notions of, say, "strength" and "weight". Finally in this constructivist sequence, a "review" of ideas would have led to "applications" and so, with considerable elegance, from the Science domain into Design and Technology. Indeed, aspects of the "intervention" phase could take the form of a focused practical task where specified areas of knowledge would be addressed through activitites to initiate cognitive conflict and lead to a re-ordering of conceptual frameworks.

Perhaps closer ties between Science and Design and Technology are desirable. Design and Technology may usefully provide contexts within which scientific ideas may grow and flourish.

It could be that a closer association between Science and Technology within the curriculum of England and Wales would pay considerable dividends. Johnsey (1999) has explored such an enhancement of links, but it is largely down to curriculum delivery in the hands of education providers as to the depth of integration they may feel is desirable or possible.

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