Technological Problem Solving as Skills for Competitive Advantage: An Investigation of Factors Associated with Levels of Pupil Success

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1. Introduction

Problem solving is widely recognised as a crucial ability in all aspects of life, not least as a core capacity in an effective working life beyond the years of formal education. Contemporary consideration for engendering a more sustainable future has arguably re-catalyzed its importance. A recent report from the OECD entitled '*Education at a Glance*' effectively considers a range of factors attributable to a country's future competitive advantage and, in doing so, draws specific attention to the significance of problem solving and technical skills. Similar recognitions can be found in other organisations such as UNESCO. Though such indicators can appear profound on a societal level, these capacities must first and always be nurtured and developed at a local level; where Technology Education classrooms provide notable potential. Indeed, it was [1] who argued over twenty years ago that problem solving was in fact the core method through which pupils undertook learning in Technology Education. Few could argue that this is different today. Moreover, the synergy offered between the problem solving method and a developing understanding for a world that continues to be technological is range of senses, offers the subject primacy in shaping such abilities for pupils. Enhanced and authentically developed problem solving abilities constitutes one important way in which Technology Education can contribute to an economically sustainable future.

In-keeping with this potential, an insightful body of research into technological problem solving (TPS) has evolved over the last twenty years, though our understanding is remains incomplete. Salient themes within this work are concerned with, *inter alia*, defining and categorising forms of TPS [2], identifying and modelling procedural features [3] and exploring the effects of different task and instructional approaches [4]. Unsurprisingly, it is true that we are building a relatively good understanding of the processes and types of knowledge involved in TPS. This being said, considerably less is known about the nature of the differences in these when considered in terms of pupils' levels of task or solution success. Arguably, the identification of what the differences are within pupils' TPS activity opens up a valuable avenue for further consideration of how problem solving skills can be enhance in the classroom and beyond through, for example, approaches to pedagogy, task and instructional design.

Despite there being a numerous types of problem solving activity that can be employed as part of the learning in technology classrooms, this study focuses upon well-defined tasks in which the solutions are realised in physical, three-dimensional forms. Specifically, it addresses the question: '*In terms of intellectual processes and knowledge, what are the differences in the modi operandi between groups of pupils that produced more and less successful technological solutions to a well-defined problem?*'

2. Methodology

2.1 Study Design

One class was chosen from each of three participating high schools giving a sample of (n=50) pupils aged 12-13yrs old. The topic area of structures was chosen within which a task requiring pupils to solve the problem of making a cantilever arm rigid was developed to allow a range of processes and knowledge types, including principles, to be explored in a physical solution. The cantilever arm modelled one side of a road traffic bridge intended to span a river. Initially, classes undertook a short unit of work on structures over three to four lessons in which pupils qualitatively explored basic forces, materials, triangulation, rigidity and turning moments. The unit was developed in consultation with and delivered by the class teachers. Upon completion, pupils worked in thirteen groups of approximately four to develop a physical solution to the set problem. All groups were given a base board and the same prescribed resources of fixed quantity including straws, card, plastic strips, thread, and glue with two fifty-minute sessions to develop and construct their solutions.

2.2 Data Gathering & Analysis

Observational data were gathered during the unit of work to measure ecological consistency between schools. Audio recordings of group discussion, structured observation and time-interval photography of the developing solutions were employed to generate a time-synced, composite representation of problem solving activity. Bespoke analytical matrices were developed to map solution development from the photographs (n=192) and NVivo was used to analyse the audio waveforms. Measures of solution rigidity and cantilever deflection were synthesized with the results of a Modified Delphi to identify the four best (high performing cohort) and the four poorest (low performing cohort) solutions of those produced. The Delphi comprised of eight expert teachers and was executed through two rounds, with face validity assessed as high overall. As part of this, solutions were ranked allowing the activity of the two most contrasting groups (best and worst of

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all solutions) to be compared in the first instance. With reference to a conceptual framework developed as part of this study, an in-depth, grounded, constant-comparative approach was employed through which areas of difference arose and were refined over numerous iterations and data passes. This gave rise to three frameworks of difference: one for process, one for knowledge and one for social & extrinsic factors. These were successively applied to ranked group-pairs in order of decreasing contrast to ascertain the extent to which differences held true for the remaining six groups.

3. Summary of Findings

By way of illustration, Figures 1 & 2 show the configuration of the best and poorest solutions. In each figure, the broken line indicates the base board given to pupils and lighter in colour a given component is, the earlier it was added to the solution. The structural integrity of the solution depicted in Figure 2 was substantially lower than that in Figure 1.

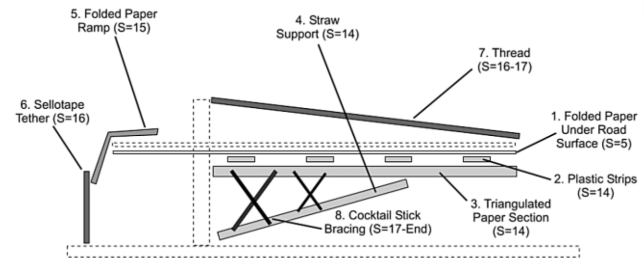

Figure 1. Configuration of Best Solution

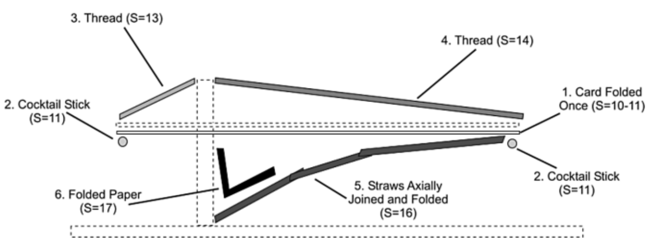

Figure 2. Configuration of Poorest Solution

Overall comparative analysis found that groups in the higher performing cohort:

1. Engaged in more task related discussion and spent longer conceptualising prior to construction.
2. Verbalised more objective knowledge correctly with greater skill/tacit-procedural knowledge in construction.
3. Successfully translated more knowledge of structures into their physical solution.
4. Utilised more positive managerial traits and fewer negative managerial traits.
5. Engaged more in reflection and more in reflection that revealed a deeper level of understanding.

4. Discussion

This study sought to identify what the differences were in problem solving activity when high performing groups were compared to low performing groups on the same TPS task. Relatively consistent differences were identified relating to use of knowledge and processes. Spending longer in the conceptual phase allowed some groups to more fully establish a starting point and plan prior to construction; something evidenced in other studies. Planning with poorer groups was generally short-term and in response to emergent problems, with greater tension evident between members. Higher performing groups integrated more objective knowledge (i.e. task requirements) into decision-making and, often, a higher level of conceptual understanding was manifest in the physical solution. In all cases, a higher level of skill during construction bolstered the structural and functional integrity of solutions. Reflection as retrospective consideration of previous actions, developments or decisions, was seen to operate on two levels, defined herein as 'declarative' and 'analytical'. The former involves statements close to the observable (i.e. that's good) whilst the later reveals evidence of a relationship between two or more elements (i.e. X did that because of Y). Higher performing groups utilised far more analytical reflection which subsequently appeared to fostering a better shared understanding between group members.

5. Conclusions

Though this study does not establish causal relationships between identified differences and TPS performance, it does identity where differences arise. Findings suggest benefit in explicitly helping pupils develop: (i) planning/management strategies for moving through conceptualisation and construction; (ii) their ability to engage in analytical reflection of the developing technological solution, and (iii) strategies to promote more comprehensive transfer of prior understanding to the final technical solution. Such measures may help in enhancing the TPS capability of pupils; something that is likely to play an increasingly important role in securing an economically competitive and sustainable future.

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