

PROBLEM-SOLVING IN TECHNOLOGY EDUCATION AS AN APPROACH TO EDUCATION FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper explores the issue of how students might learn about sustainability in technology – education classrooms and the relevance of problem-solving in that learning. One of the emerging issues in technology education research is the nature of problem-solving specified in curriculum documents and the kinds of learning activities undertaken by students in technology education classrooms. In parallel with our developing understanding of the characteristics of good technology education programs is the inclusion in recent curriculum documents of the concept of sustainability or sustainable development. However, as yet there is little information about how technology students think about sustainability and how they might best learn about it. This is of particular interest because in technology education, sustainability is often described in curriculum documents as an issue that is intended to be integrated within design projects and activities, rather than being the topic of a classroom lesson as might happen in a subject such as environmental studies. This paper explores current understanding of the issue generally and within technology education. It concludes that the design, problem-solving approach that is common to technology education classrooms provides many affordances to students engaging meaningfully with ideas of sustainability and of developing strong understandings of its scope and significance.

INTRODUCTION

The issue of sustainability in technology education has emerged in relatively recent times (eg Pavlova, 2004; Elshof, 2007; Pavlova & Pitt, 2007). To date little research has been conducted to examine the nature of existing or possible relationships between sustainability and the nature of learning in technology education. Exploring the issues that relate to the relationship between learning processes and sustainability is the purpose of this paper. The paper is structured in the following way. Initially, the ways learning occurs in technology education are examined to provide a baseline for understanding learning in technology education. Then, the emergence of sustainability as an issue in education in general, and in technology education curricula specifically, is explored. Finally, research findings and curriculum documents are examined to develop some preliminary conclusions about the current and possible future relationships between student learning in technology education and sustainability.

PROBLEM-SOLVING AS THE MAJOR FOCUS OF TECHNOLOGY EDUCATION

One of the key features that appear to be common across technology education curriculum documents is the emphasis on problem solving (Barak, 2007). This is often expressed in terms of the need for students to engage in a particular form of problem solving, often described in terms of a design process. In a study conducted in England and Wales, Johnsey (1995), found that there was a variety of ways in which the design process was being described and identified seventeen distinctly different descriptions. However, in each of the descriptions Johnsey provided, problem solving involving the

identification of a task (by either teacher or student) that was potentially complex because the nature of the task was unclear, as was an appropriate solution and the way or ways to achieve a solution.

The issue of problem solving deserves some attention as it can now be found in almost all curriculum documents from mathematics to science to social sciences as well as in technology education. Problem solving is seen to be an appropriate learning process to achieve expertise (at some level) in many subjects. In most areas of the curriculum, problem solving is concerned with students developing the ability to solve non-complex problems, or problems where innovation or creativity is not required. These consist of problems where the nature of the problem is clear, the solution is known at the outset (at least to the teacher) and there are a limited number of known ways to solve the problem (Newell & Simon, 1972). An experiment in science or a mathematics problem is of this type of problem. Appropriate teaching for the solving of non-complex problems is reasonably well known and involves, according to Stevenson:

...trying to assist learners to establish the right kinds of schemas-schemas that involve deep structured conceptual understanding for apprehending the appropriate nature of the problem and closely linked procedural knowledge for execution at the appropriate level of abstraction-as well as associated declarative and procedural metacognitive knowledge for the strategic control of problem solving.

(Stevenson, 2004, 126)

Problem solving models

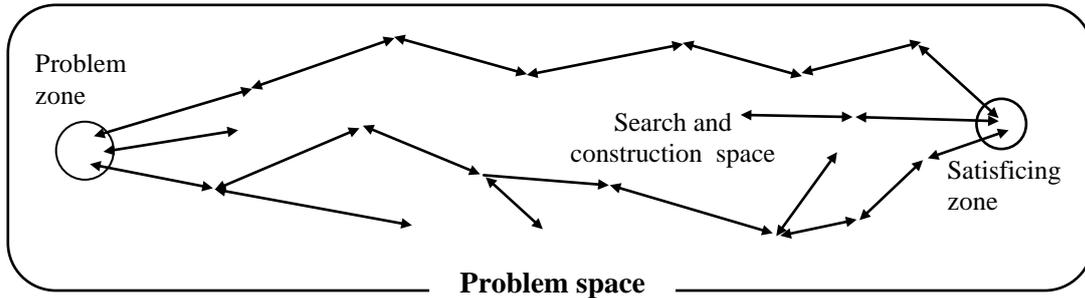
Newell and Simon (1972) developed a model to characterize problems and the way people solve them that have been used in research for many years. In the model problems were said to occur in a problem space which consisted of three elements: 1) a problem state, which was the statement of the problem; 2) a goal state, which was the solution; and 3) a search space, which was all the information in memory or elsewhere that might be used in finding a solution. Problem solving was said to be a process of navigating the search space between problem state and goal state.

However, the model was based on how people solve simple problems, sometimes described as instrumental problems, where all aspect of the problem were known or knowable. In fact, the model was based largely on an analysis of a primary school student solving a mathematical problem. In a study examining the utility of the model in characterizing the complex, ill-defined problems encountered by design students and architects, Middleton, (1998) concluded that Newell and Simon's model was unable to account for the features of the problems or of the way people solve them when engaging in these design-based activities, which Churchman (1967) called 'wicked problems'. Churchman was attempting to capture the essence of why design problems were complex.

Middleton revised the Newell and Simon model to accommodate the features of design problems by modifying each of the three elements of the model. Thus the problem state became the problem zone, to account for the reality that different people might represent a given design problem in different ways. The goal state became the satisficing zone, to account for the fact that with design problems, there was no one correct solution and that any solution represented the best efforts a designer could come

up with in a given circumstance. The search space became the search and construction space, to account for the reality that design solutions are often a mix of existing knowledge and new ideas. Middleton’s model is represented in Figure 1.

Figure 1, Revised concept of a problem space (Middleton, 1998)



Middleton’s model has been useful in understanding the characteristics of design problems and of the ways people attempt to solve them. It is possible to utilize the model to represent sustainability issues. For example, the issue of providing environmentally sustainable transportation can be represented in various ways within the problem zone. It can also be seen as having a variety of solutions and processes to achieve those solutions.

In the next section the emergence of sustainability in education is outlined. This draws largely on Australian examples, however, the context for these developments are international in that they are driven by such things as the Bruntland Report (1987), the Rio Summit (UNCED, 1992) and the Kyoto Protocol (United Nations, 1998). After which the current situation and possibilities for sustainability within technology education curricula are explored.

THE EMERGENCE OF SUSTAINABILITY IN EDUCATION GENERALLY

In addressing the issue of the emergence of sustainability, coverage is restricted to Australian sources. This is done principally for reasons of economy, but the small amount of information from other countries suggests the picture is similar in most developed countries. In summarising the emergence of sustainability as an issue Middleton (2004), noted that the emergence seemed to have three aspects. The first was the evolution of what sustainability meant, which was characterised as “what to talk”, or, the definitional discourses on sustainability. The second examined the extent of the debate, which was characterised as “talking the talk” which includes who’s talking, how much talking is being done and how the talk has changed over time, The third examined what was happening in schools which was characterised as “walking the talk”.

In exploring definitions in terms of education (what to talk) the term sustainability appears to have oscillated through at least four competing meanings internationally over the last forty years. The four meanings can be characterized as (a) sustainability as environmental education (Ryan, 2000), (b) as sustainable development education (Ryan, 2000), (c) as sustainable growth education (Fien, 1988), and (d) as encompassing the concept of social, economic and environmental sustainability

(Collins, 1992; Pavlova, 2004).

Earlier approaches saw sustainability as synonymous with environmental education (Lucas, 1979; Greenall, 1980; Fien, 1988). While there is evidence of environmental education from early in the twentieth century (Gough, 1997), the need for an educational response to the growing problems of pollution and depletion of natural resources received significant attention only in the 1960's. Lucas identified three models of environmental education in these early approaches to sustainability. These comprised education *in*, *about* and *for* the environment. Education *in* the environment refers to activities conducted within the natural environment, with the intention of fostering positive attitudes to the environment. Education *about* the environment was concerned with explaining natural systems, and education *for* the environment was concerned with educational activities that: *aim to promote a willingness and ability to adopt lifestyles that are compatible with the wise use of environmental resources* (Fien, 1988, 7). The discourse was synonymous with environmental education being a moral good, but something that was seen as not necessarily connected with society.

Sustainability as sustainable development education has evolved within the environmental education area and has developed as a counter to the idea of sustainable growth. That is, the idea of continuous growth is challenged and the idea that growth should only occur if it is compatible with the aims of using environmental resources wisely. The sustainable development approach is also conceptualized in global terms that encompasses the notion of sharing the resources of the world, so that as well as achieving environmental goals, equity issues might be addressed. Against the sustainable development approach, the approach of sustainable growth takes the idea of continuous growth as a given, with issues of sustainability being concerned with facilitating this growth.

Sustainability as sustainable growth (and education) is, in essence a response in keeping with an economic rationalist model of society. That is, economic growth is considered as always good for society and the sustainable growth approach is the means by which we ensure this growth is able to continue. The assumption that economic growth is always good implies that this is not negotiable. What is negotiable in the model is the nature of acceptable side effects. For example, the then Australian Government refused to sign the Kyoto Protocol on greenhouse gas emissions because it holds the belief that it would hinder economic growth. Thus, sustainability is seen firstly in economic terms, and only then in environmental or social terms.

The concept of sustainability addressing more than environmental and equity issues is one that has received little attention over the last forty years. Collins (1992) addressed the issue, especially for those in education, by questioning education's approach to three issues. The first is the way in which education deals with natural reality, where Collins argues educators have attempted to cut science off from consideration of other human goals, such as the creation of a good society. Collins argues this occurs because scientific empiricism has favoured approached to understanding reality that concentrate on breaking things down to their component parts which reduces the capacity to understand connections between parts. Secondly, Collins argues that current economic and social patterns are treated in education as natural phenomena rather than human-created patterns of behaving that can be changed. Lastly, Collins argues that curricula need to be changed to encompass consideration of what a good life might be and of

how we provide an education for living a worthwhile life. Thus, Collins regards sustainability education as connecting how we think about the environment, society and the economy and understanding that they are interdependent. There appears, however, to be little evidence of discussion about this fourth approach to conceptualizing sustainability education during the latter part of the 90s. Indeed, one could be excused for thinking that the dominant approach over the last few years is based on the sustainable growth paradigm.

In searching for evidence for “talking the talk” state and federal government education documents were examined. All state governments in Australia have developed policies about education for sustainability. A sample can be found in one state government policy which includes the following:

The paper recommends that the education systems and schools include education for sustainability as their primary purpose. At the policy level, it recommends that education systems develop a vision for a sustainable society and orient towards learning for sustainability. It recommends that education for sustainability be mandatory in Western Australia. Also at the policy level it recommends an overturning of the policy contradictions which result in school based limitations to education for sustainability and environmental action. At the schools level, it recommends a continuation of, and greatly increased locally initiated and developed educational responses to issues of biodiversity loss and unsustainable consumption. Finally, it proposes a four stage model for schools to refer to as a community development path for learning towards sustainability.

(Wooltorton, 2002, 2)

The question of “talking the talk” is one of policy, with government departments providing extensive policy documents and a range of programs designed to improve the existing approaches to sustainability education in schools, which, by implication, are not yet regarded as satisfactory.

APPROACHES TO SUSTAINABILITY EDUCATION IN SCHOOLS

In examining Australian school responses to education for sustainable development (ESD) a particular approach was adopted. With the exception of a number of small research projects referred to earlier (Pavlova & Middleton, 2002; Pavlova, 2004), few research reports examining school responses to ESD exist. To account for this, reports prepared by government departments and semi-government agencies such as the Australian National Curriculum Corporation were used to provide the main evidence.

Historically, approaches to sustainability education in Australian schools place it squarely within environmental education. However, tracking the development of sustainability education approaches in schools over the last forty years, in whatever title it appears under, is problematic. Some clues to the history can be gained from the findings of the Curriculum Corporation’s review of environmental education in schools (Curriculum Corporation, 2002). The review found that: *key topics such as biodiversity, sustainability, greenhouse and endangered species, are under represented or missing from state and territory curriculum documents DEH, 2002, 3).*

Indeed, the terms environmental education and sustainability education are often used interchangeably. The Commonwealth Department of the Environment and Heritage has a number of projects concerned with environmental education in schools. In 2002 funding was provided for pilot projects in New South Wales and Victoria. The projects are part of what is called the Sustainable Schools Program (DEH, 2002). The program is defined as: *the integration of existing and fragmented approaches to sustainability education into a [sic] holistic program with measurable environmental, financial and curriculum outcomes* (DEH, 2002, 1),

The implementation of sustainability education at the primary school level in Australia appears to have been and still is, problematic. This may be the result of primary school teachers being overwhelmed by the demands of the key learning areas initiatives, where they have been required to make changes in all the KLA's, which means the entire curriculum. Other curricular and pedagogical initiatives may also have adversely affected primary teachers' capacity to engage with issues of sustainability.

In a study examining the knowledge about environmental education of Queensland primary school teachers Cutter (2002), found that teachers had little knowledge of the concepts, theories and teaching approaches, and tended to dismiss the importance of knowledge, placing greater importance on attitudes and values. Cutter argued that such an approach was inadequate for developing environmentally literate students.

Approaches to sustainability education in Australian secondary schools appear to be rather fragmented. The evidence for this is not direct data from schools or school documents but rather from the state and federal government initiatives such as the Curriculum Corporation review of sustainability education and the Sustainable Schools Project. The background material for the Sustainable Schools Project argues that it is necessary to provide some coordination and cohesion of what the reports regard as the fragmented efforts of schools.

One area of sustainability education that was revealed in the research undertaken for the paper was in non-formal approaches. There are a variety of approaches, facilitated by electronic and web-based resources for interested people and schools. To these can be added resources such as the UNESCO funded material by Fien (2003), which provides well presented and appealing teaching materials for addressing sustainability.

One point worth mentioning is that among the fragmented approaches, one feature does seem to have emerged. Environmental education programs initiated in the 70's tended to concentrate on directed learning supplemented by the occasional visit to an environmental site to illustrate particular points. This appears to have been of limited value in terms of developing students' understanding of sustainability issues or of changing attitudes to those issues (DEH, 2002). This seems to have changed to the point where learning about sustainability, or the environment is conducted via the medium of projects where the issue at hand is problematised. These projects appear to be interesting and motivating for students, being ones where active involvement in tasks that should appear authentic and meaningful was often employed. The question of coordination and coherence are still there, but the individual learning activities show some promise. What appears missing in these changes is a more holistic approach that explores more than the environmental aspect of sustainability, in terms expressed by

Collins, (1992) and Pavlova, (2004, 2006)

THE EMERGENCE OF SUSTAINABILITY WITHIN TECHNOLOGY EDUCATION IN AUSTRALIAN SCHOOLS

Sustainability, as an issue that is seen by technology educators as a natural part of their teaching responsibilities, is a relatively new idea. Indeed, until comparatively recently, issues concerned with the depletion of natural resources were seen to be antagonistic to many technology teachers, and an area where they felt themselves to be vulnerable. Drawing on work by Ellul (1990) and Vernadsky (1945) Pavlova (2006) argued that the various approaches to sustainable development can be located on a continuum which has at one end “technological fix” where the belief is that technology can solve any problem. On the other end is “value change” where the solution requires a more holistic approach to the problem. Many technology teachers would see themselves as having a strong belief in technological fixes for most human problems. Pavlova argued that such a view is in accord with the sustainable growth approach (as opposed to the sustainable development approach) which is allied with the dominant social paradigm and a belief in the value of unfettered growth.

The major stimulus to curriculum changes that challenge the determinist view of technology within Australian Schools was the introduction of the Technology Key learning Area (KLA) in 1994 (Curriculum Corporation, 1994). The Publication of the document, *A Statement on Technology for Australian Schools*, introduced and endorsed a new approach to teaching and learning within the Technology KLA. The basis for learning, and hence teaching, was the problem-solving based, design process. Prior to the introduction of the KLA, technology type programs were based on approaches where the content and process of learning was determined by the teacher and the tasks were not regarded as being in any way problematic. The Technology KLA, in introducing the design approach, made it clear that students would be involved in researching the issues surrounding particular problems, and in some instances, students would be involved in identifying the problems to be addressed. Furthermore the statement included explicit mention of sustainability or issues within the gambit of sustainability. For example:

People need to make informed decisions about the sustainable development of technology and its impact on people and the environment..... (p3)

Social and environmental changes in Australia make it imperative that people become more innovative, knowledgeable, skillful, adaptable and enterprising (p4)

Through the technology learning area, students experience a variety of technologies that, among other things:

Are ecologically desirable and sustainable (p6)

The Technology KLA was a national document that had to be translated into state syllabus documents, and more importantly, into classroom practice. However, all states have accepted the design process (albeit with Queensland calling it Working technologically). Furthermore, in articulating the individual state syllabus documents, the issue of sustainability has emerged as an explicit element in all states’ documents. For example, the Technology syllabus document for Queensland includes consideration of sustainability under the heading of appropriateness:

Appropriateness

Students consider many perspectives before making judgments about the appropriateness of:

Design ideas

Processes and products

The possible impacts of these on users or environment.

*In particular, they consider, and make judgments about, **aesthetic, cultural, economic, environmental, ethical, functional and social** appropriateness.*

(Queensland Studies Authority, 2003, 2)

The above material is at the curriculum document level. As foreshadowed earlier, the picture at the school level in Australia is more complicated. The data at this stage are patchy, scarce and much of it anecdotal. For example, in the 90's one of the state technology associations in Australia decided to send to members, with the membership renewal package, a packet of seeds for trees grown and harvested in that state. Would the association have described itself as 'green' or 'sustainable'? Probably not. It is more likely that their reasoning was that their state economy relied heavily on forestry, the timber industry and technology education teachers consumed trees, so it's a good idea to replace them. That is, teachers had an understanding of the necessity of taking action about an issue that can be seen as one part of the overall issue of sustainability. However, the understanding is tacit, local, and grows out of reasoning based on observation and practice.

The findings of a more recent study (Pavlova & Middleton, 2002) found views of teachers that were consistent with those of the story above. In the study, a number of heads of technology departments in High schools in Queensland in Australia and in Novgorod, St Petersburg and Petrozovodsk in Russia were interviewed about the more general issue of values. All were selected on the basis that they were regarded as progressive educators. The questions sought teachers' views about three aspects of values: values and technology education; teachers' views about the relationship between values in technology education and effective teaching; and values in technology education and values in other subject areas. The findings revealed that both Russian and Australian teachers believed values were an important part of technology education and could be dealt with more effectively because of the meaningful context of technology education.

MEANINGFUL ENGAGEMENT BY STUDENTS WITH SUSTAINABILITY PROBLEMS

The issue of how students learn, and particularly how they engage in problem solving in technology education has been the subject of some research and much debate for many years (for example Johnsey, 1995; Middleton, 1998; Walmsley, 2003), though there are fewer empirical studies. One recent study by Walmsley (2003) explored the differences across traditional and design-based technology education classes in terms of students' perceptions of their learning environment. Walmsley used the Cognitive Holding Power Questionnaire (Stevenson, 1998). This is an instrument that collects data that provides measures of the extent to which any learning environment 'presses' students in

that environment to engage in higher or lower order thinking. Walmsley found that students engaged in higher-order thinking more often in design-based classes than in traditional classes. Unpacking the instrument reveals that the key indicators of a learning environment that encourages higher-order thinking is students having the sense that they have a large share of responsibility for the conduct of the design activity, and thus of their learning.

In attempting to draw connections between problem-solving and sustainability there are three aspects that provide a basis for such connections. The first is the growing recognition of a more holistic approach to sustainability. That is the approach advocated by Collins (1992) and more recently by Pavlova (2004). In this approach sustainability is seen to include social and economic issues as well as environmental issues. Such an approach is compatible with most contemporary approaches to technology education, where students develop design solutions to real problems. The value of linking sustainability issues with design-based programs is the meaningfulness of doing so for students. That is, to consider the disposal issues related to using one particular material over another can be seen as relevant by students and not an irrelevant add-on.

The second basis for making a connection between technology education and learning about sustainability is that design has forced a new conceptualization of problem solving to accommodate the characteristics of design problems, outlined earlier in this paper in terms of a revised model (Middleton, 1998). The significance of the revised model in terms of the link between sustainability and technology education is the reality that many issues that one would deal with as sustainability problems with students can be defined as complex and ill-defined and require creative solutions to resolve. In that sense, issues of sustainability are essentially design problems.

The third link between an holistic notion of sustainability and technology education is contained in Simon's (1986) view of design. Simon argued that all learning could be located in one of two categories. Simon labeled one category the natural sciences and the other the science of the artificial. The natural sciences in Simon's categorization correspond to contemporary ideas about science. Simon described the science of the artificial as corresponding to a particular view about design. Simon went on to characterize the natural sciences as being concerned with understanding 'what is', while he characterized the science of the artificial as being concerned with 'what might be', that is, a design activity with an explicitly normative purpose, rather than about producing faster, bigger, shinier products.

This normative property of technology education provides a powerful rationale for addressing sustainability in technology classrooms. This, together with the importance of problem-solving in technology education curricula make for a good 'fit' between this process and learning about sustainability.

It is argued here that an explicit emphasis on problem-solving in designing solutions that contribute to making the world a better place is an important component of a technology education program. It does need to be said, however, that while the match between ESD and technology education is conceptually strong, there are still significant barriers to overcome in terms of attitudes, curriculum resources and professional development for teachers. These are perhaps the next challenges.

CONCLUSIONS

In this paper an attempt has been made to draw out the important features of contemporary learning in technology education, with particular emphasis on problem solving that involves complex, ill-defined problems. Then the emergence of education for sustainability was outlined, and the small amount of research about this issue within technology education surveyed. Finally, it was argued that there are important reasons for the linking of education for sustainability with technology education. These include the compatibility between the normative properties of design problems and sustainability issues and the facilitation of higher order thinking in design problem solving and the utility of this in addressing sustainability issues in technology education classrooms.

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