From the Editor

Musings about Technology and Engineering Education

P. John Williams

I recently attended a Technological Learning and Thinking Conference in Vancouver, British Columbia after which I was privileged to spend some time touring through the Canadian Rocky Mountain area. It was summer (or so the calendar said) so the countryside was green, the rivers were gushing, and there seemed to be a lot of snow, at least to an Australian. This is the context that shaped the thoughts which follow.

As I travel in new areas, I am always interested in the schools that I pass. They are generally recognizable because schools look like schools regardless of the country you are in. I recall this was particularly the case when I traveled through Zimbabwe soon after that country achieved independence when there was a massive increase in state funded education to achieve the goal of primary education for all. There was no time to design schools to suit their environment, so all the hundreds of schools that were built in the first few years of independence in the early 1980's were exactly the same.

I wonder what type of technology education goes on in the schools that I pass. I try and see an indication of technology activities and usually find it near the rear of the school; sometimes the evidence is in the form of dust extraction hoppers or wire fences full of vehicles in various states of deconstruction. As I passed schools in the Canadian Rockies, I wondered what type of technology programs might be offered that would be relevant to the students in those schools. Given the context, I thought of technologies surrounding the sports of rafting, fishing, skiing, and snowboarding, or those related to resource conservation and depletion of the currently vast coniferous forests.

A number of presentations at the Vancouver conference had touched on the importance of context when designing technological activities for children; it is the context that makes experiences relevant to students and so enhances their learning capacity. I thought of technology curricula with which I had been involved where the context is reflected in the curriculum content. In Seychelles,

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for example, one of the technology curriculum content areas is fishing. This is relevant because of the large commercial fishing industry which runs out of Seychelles, but also at the personal level many individuals enjoy fishing, and fish comprise a significant aspect of Seychellois diet. Many of the schools in the country are within a couple of hundred meters of the ocean, so it is avery familiar aspect of life to students.

In Botswana, mud brick construction and traditional building were part of the technology curriculum. Many students lived in mud brick houses, the design of which had evolved over many years to be particularly appropriate to the environment – the bricks come from the earth and eventually return to it.

The notion of relevant context also applies to national curriculum design. The technology curriculum of any country is a product of the history of that country and reflects the prevailing social attitudes toward education and technology. Diversity in technology education across the world is therefore inevitable. I think of the audacity of the Jackson's Mill curriculum project to proclaim the universality of the 'grand narrative' curriculum organizers that were developed at that time (communication, production, and transportation). In the current post-modern climate of respect for situational developments and local contexts, such declarations would probably not be made. However, it is clear that curricular developments in some countries are strongly influenced by other countries. For example, the history of technology education in Australia can be quite clearly linked to developments in the United Kingdom, as is the case with a number of other Commonwealth countries.

The Standards for Technological Literacy are a case in point. No claims are made anywhere in the Standards documentation that they might be appropriate for use anywhere other than the USA. Despite this they have been translated for local use in Germany, Finland, and Taiwan, but have not had a major impact in those countries. They have also been used in limited ways in Chile, Spain, and Cyprus. Such limited influence of the Standards on international technology education curriculum is appropriate at a time when the significance of the local context is recognized.

The current thrust of technology education toward engineering in the US is an interesting case in this context. One would not expect this development to have a significant influence on other technology education systems around the world, except that the STEM movement is concurrently developing momentum in a number of countries. In both the UK and the USA, the overall thrust of STEM is the coordination and alignment of previously disparate initiatives in the four areas of science, technology, engineering and mathematics.

Back to the Rockies, and my musings moved to consider the implications for school technology programs if they were called engineering and not technology. Could students still study snowboards for example, develop an understanding of the properties of materials and their application to this context, and then design and produce one that matched their conditions and needs? Or could they do a project on forest conservation and examine the effects of the mountain pine beetle on the timber industry? Probably, but not as logically as if it was a technology program.

What about those aspects of national curricula that are seen to be important areas of study in developing students' technological literacy? Could students still study fishing in Seychelles, both from national and personal perspectives, if the subject was engineering and not technology? Fishing would be difficult to justify as engineering, despite being a technologically rich area of study.

It would also be difficult to include mud brick construction as part of an engineering course in Botswana. Superficially, construction engineering is a significant branch of the engineering profession, within which a study of brick-making could be considered. However, the nature of this specific application, mud bricks, seems to be technology rather than engineering. The current state of this art of mud brick construction is the result of years of trial and error which eventually produced an efficient and effective design – this is technology. Engineering would do all the quantitative analysis and testing prior to production, and so ensure that the first batch of bricks worked as was intended.

The bricks could be deconstructed as part of engineering and analysed to explain the design/process/product in engineering terms, but this would be after the event, and would not constitute design nor the consequent development of new knowledge through design.

My traveling companion in the Rockies was a lady from South Africa who had just completed her doctorate on Indigenous Technology, which is a part of the technology education curriculum in South Africa. In discussing the implications for a study of indigenous technology in the context of a subject called engineering, her feeling was that it would be a lot more limiting. One of the areas she explored as a significant indigenous technology was fermentation, which is studied as part of the technology curriculum, but would be difficult to incorporate in a subject called engineering.

Of course, after having expressed the need to respect localized history and developments in the design of new curriculum, these musings have little to do with the change from technology to engineering in the US, However, they may provide a hint that a more narrow type of technological literacy could be the outcome of studies in engineering when compared to technology.

I have some concerns about the move to engineering, particularly in a STEM context. Being currently involved in the battle in Australia to ensure the place of technology education in the new national curriculum, I empathize with the desire for credibility, recognition, and understanding. However, let me outline a couple of my concerns.

The Rationale

The rationales for the engineering agenda are various but limited, and related mainly to vocational and economic goals which arise from shifts in workforce patterns and downward trends in economic indicators—it is not uncommon for curricular development in technology education to be promoted in periods of economic downturn. Such rationales are not uncommon in technology education, though they have more recently been marginalized as technology education in many countries has established its place more securely as a component of general education. Traditional technology education had a strong vocational emphasis and consequently the link with workforce needs and the economy was quite explicit. Technology as a component of general education has a less direct link with economic development, but nevertheless it remains a rationale which is often invoked.

The current rationales for engineering include:

- Increase interest, improve competence, and demonstrate the usefulness of mathematics and science.
- Improve technological literacy which promotes economic advancement.
- Provide a career pathway to an engineering profession.
- Improve the quality of student learning experiences.
- Prepare for university engineering courses.
- Elevate technology education to a higher academic and technological level.

There is a disconcerting lack of rationale related to the promotion of the individual's personal development as a technologically informed member of society. A useful type of technological literacy would essentially be broad, encompassing many aspects of technology, not just engineering, and this may be why there are few engineering rationales which focus on the development of the individual.

The Confused Acronym

My assumption in this discussion is that the scope of technology is broader than that of engineering, If it is accepted that engineering is a subset of technology, and there are many technology areas that are not engineering (architecture, industrial design, biotechnology, computing), this would seem to be a plausible assumption. So if technology education potentially dealt with the breadth of technology, then engineering as a subject would be essentially more limited. Given that one of the virtues of technology is that teachers can choose to teach aspects that are of interest to them and relevant to their students, it would seem that limiting this scope would be a disadvantage.

STEM is a confused acronym: engineering has a different type of relationship to technology than does science or mathematics because it is actually a subset of the broad area of technology. The science equivalent would be to link science, biology and mathematics, for example. While some apologists have developed rationales for the consideration of technology as a discipline, it really is interdisciplinary and relates to engineering, along with a range of other disciplines in both the sciences and the arts.

Inequitable Emphasis.

When technology is aligned with another curriculum area in schools, it invariably gets undervalued. Science and technology as a subject in primary schools results in the prioritization of science. Science and technology offerings in secondary schools tend to be quite academic rather than practical. Numerous science, technology and mathematics (STM, SMT or TSM) projects that have been developed around the world produce interestingly integrated curriculum ideas and projects, but rarely translate into embedded state or national curriculum approaches. This is partly because the school and curriculum emphasis on science, technology and mathematics is not equivalent across these areas. Even the earliest integrated approaches involving these subjects served the need for reform in science and mathematics rather than the goals of technology. History and research indicate that technology will be undervalued when aligned with science and mathematics (and maybe engineering as well).

The Process

There seems to be a developing consensus that the fundamental difference between the design processes in engineering and technology is the absence of mathematical rigor and analysis in technology that precludes the development of predictive results and consequent repeatability, although this is being questioned in recent research. This thinking has led a number of authors to categorize design into conceptual design and analytical design, the former being common in technology education and the latter a part of engineering.

The process of engineering design involves problem factor analysis which is dependent on an understanding of applicable science and mathematics. Analytic design may be utilized to ensure functionality and endurance and involves static and dynamic loads, and consequent stresses and deflections. Conceptual design is less predictive. Success in technology is determined by what "works," which is initially defined by a range of criteria, and through a process of research and idea development, a solution is produced and then judgments are made about its success. In technology, it is not possible to predict what will work with certainty because of the manifold qualitative variables involved. It is a process of experimentation and modeling that leads to a solution. In engineering, experimentation and modelling lead to the verification of a solution, prior to its development. This confidence in a predetermined solution is obviously essential, given the nature of engineering projects. So in engineering, the design criteria are more deterministic, implying that a more limited range of outcomes are possible and there is less opportunity for divergent and creative ideas to develop. In technology, the design criteria are more open, permitting a broader range of acceptable outcomes. My concern here, therefore, is that engineering design provides less scope for the achievement of the general goals related to creativity and lateral thinking because it is more constrained.

Vocational and General Education.

Engineering as a school subject has a pre-engineering or vocational goal, and will necessarily employ a design process that is aligned with the nature of engineering design—one that is more analytic and based on a defined body of knowledge. However, some authors and curriculum development projects promote engineering design in lower secondary and even primary schools, which at this level should not be vocational but general. A design process at these lower levels of education which prioritizes analytic design and is preceded by the mastery of a body of knowledge, and consequently limits creativity and divergent thinking, is inappropriate. Projects such as "Primary Engineer" are really engaging in Design and Technology for general education purposes and presumably use the engineering label for reasons related to status or recognition.

There is an explicit vocational approach in the STEM agenda, mainly in terms of science and engineering. While the government paints a broad approach to vocational goals and refers to increasing the flow of qualified people into the STEM workforce, it's more specific concern is the large number of engineering graduates from developing countries and the concurrent decline in the number of domestic engineering graduates. Project Lead the Way represents an integrated approach to STEM education and specifies one goal of preparing students for university engineering courses. A number of researchers also see STEM education as providing a career pathway to an engineering profession. In this context, the validity of such a strong vocational bias is questionable, and it is reasonable to question the morality of exposing all learners to STEM when only a few of them will go on to STEM based careers.

STEM education is also being proposed as a component of general education, by endeavoring to improve the level of STEM literacy in the population and increase STEM skills overall for everybody. The basic incompatibility of general and vocational approaches in one course has been well established: the goals of each are different, as are the assessment methods and the fundamental teaching methodologies.

The Place of Knowledge.

What knowledge is relevant in the study of engineering and technology? If a particular context area of engineering is being taught, such as civil or automotive, then there is a defined and acceptable body of knowledge related to that area that forms the parameters for the development of design projects. However, this is not the case with technology as there is no defined body of knowledge. So the question arises, what knowledge is relevant?

The answer to this question defines a difference between engineering and technology. In technology, the relevance of technological knowledge to a problem or design brief is defined by the nature of the problem. The information that is needed to progress toward a solution of a technological problem becomes the body of relevant knowledge, which of course cannot be defined prior to the analysis of the problem. This, therefore, also specifies the accompanying pedagogy and that content cannot be taught in the absence of a design problem. The design problem is analyzed, possible pathways to a solution are projected, and then the solution is pursued. These determine the knowledge that is relevant.

In engineering studies, the context, which defines the relevant body of knowledge, is predetermined, be it chemical, marine, automotive, etc. Because the context determines relevant knowledge, it is not dependent on the nature of the design problem. Thus the task for the student is different in engineering than it is in technology.

The knowledge needed to solve a technology problem is ill-defined until the nature of the problem is fully explored and the design process is underway. The knowledge needed to solve an engineering problem is pre-defined by the type of engineering that is being studied, so there is less scope for the student to explore and, consequently, to define relevant knowledge.

Curriculum Clarity

At the moment there seems to be little clarity about what STEM education might look like in schools. It would require a very radical curriculum approach to take out all the time in the school day that is now occupied by science, technology, and mathematics and replace it with a sequence of learning activities that would represent an integrated approach to achieving the essential skills and knowledge of these three subjects, plus engineering. This ambiguity extends to how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed.

Even if an integrated curriculum was possible, it is probably quite unrealistic to expect such an approach to be successful in the short term in secondary schools because of the staffing implications. Primary school teachers generally already teach all subjects to one class of students, so an integrative approach is not such a radical approach at this level. Individual secondary teachers, however, would not be able to develop the expertise required in all the STEM subject areas to enable just one teacher to provide an integrated approach. Therefore a system of team teaching would be necessary, along with all the accompanying school organization and timetable implications. Teachers would need to be trained for this type of approach.

One of the goals promoted by the STEM agenda is “STEM literacy.” As a vague idea this is laudable, but as an educational outcome it is problematic. Scientific literacy, technological literacy, and particularly numeracy are reasonably well researched and defined, but something that is an amalgam of the three has neither been developed nor trialed and tested. Consequently, it is difficult to develop an academic program (STEM) when the goals are not defined.

One implied definition is provided by Sesame Street’s Early STEM Literacy Initiative which has a major focus on mathematics in the early years, and is formally a part of a two year science initiative related to developing an understanding of the natural world. If this approach, that prioritizes mathematics and science, represents STEM literacy, then the goals of engineering and technology are ill considered.

As with many curriculum developments, the curriculum changes are made before the rationales are explored and verified. The trend from technology toward engineering in the US is well established and cannot be reversed even if there was a will to do so. Therefore my concerns are not pleas to desist but rather a call for needed research to ensure that this significant curriculum change is successful by initiating informed argument, highlighting the need for a sound philosophical rationale, and conducting carefully structured investigations.

Editor's Note

John Williams has been a member of the JTE Editorial Board since 1994. In addition to his distinguished service to this publication, he has provided an international perspective to our work and has mentored several international authors in publishing between these covers. He is serving as honorary editor for this issue.

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