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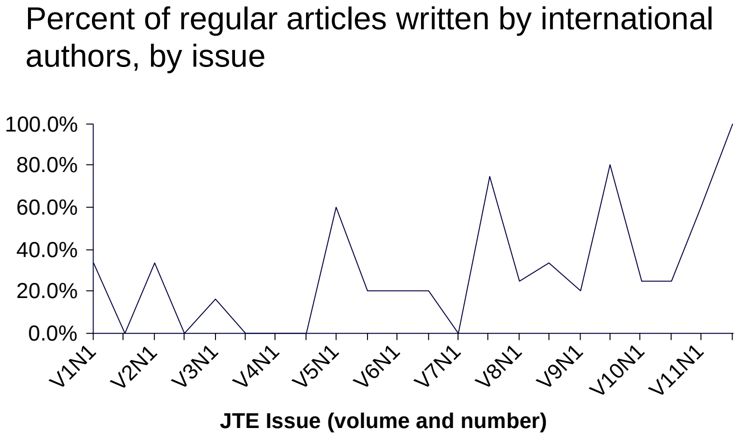
From the Editor

It’s a Small World After All

When our three children were youngsters, one of their favorite songs was “It’s a Small World After All.” They played the song over and over until the record finally wore out. I grew very tired of the song and I am thankful in some respects that permanent media like compact disks were not around back in those days. Nonetheless, I was able to satisfy my desire to reminisce about our children when they were young by accessing the Disney site on the World Wide Web and listening to that song.

A new version of that song has been bouncing around in my head recently. I sensed that there was an increasing international presence in the *Journal of Technology Education*. Petrina (1998) addressed the number of international articles published in the JTE in an earlier, thought-provoking piece. He did not present his analysis, however, over time.

The graph below shows the percent of regular articles (those that go through the refereeing process and appear under the section titled “Articles”) by issue, from volume 1, number 1, through the current issue. To be included, at least one of the authors had to be international. Percents were used to plot the graph since the number of regular articles varies from one issue to another. The graph line is quite uneven due to the small range of the values. However, one can easily observe that there are more articles in recent years written by foreign authors.


Percent of regular articles written by international authors, by issue

To analyze the data further, I compared the number of articles written by international authors in the first eleven issues to the number in the most recent eleven issues. The data showed that 16.3% of the articles were written by international authors in the earlier group compared to 41.7% in the latter. This represents a dramatic increase and is evidence of the changing nature of the JTE.

As I completed my analysis, I realized that, by chance, it was quite timely. Every one of the regular articles in this issue was written by an international author. Moreover, the issue contains a book review written by a person from Canada and it is on a book written by a person from Germany. It seems that yours truly is the only non-international entity in the entire issue.

Part of the reason why this has happened is simply due to chance and the timing of manuscript acceptance. The notion, though, of having an international flavor in the JTE was not an accident. Founding editor Mark Sanders maintained a strong international presence among the Editorial Board members from the very beginning and this continues today. But it does not particularly explain away why the international influence has increased in recent years. I have speculated about cause and effect, but I am not prepared to offer my conjectures at this point.

I am confident, though, that the walls that we now tend create in our minds about the national origin of scholarly journals will continue to come down. The increasing number of scholarly journals that are accessible electronically confirms that the Web is truly World Wide. Several journals directly followed the leadership of the JTE in this regard.

Language translators have started to appear on the Web as well, with great promise to eliminate many of the barriers of language. Right now, prospective JTE authors for whom English is a second language are often disadvantaged in the review process. The resources are simply not available to translate and edit a manuscript into English. Plus, such work must yield a high quality product of English prose, not something that simply meets minimal language standards. This impediment will likely dissipate as the language translation technology just mentioned is developed further. The walls will disintegrate even more.

Despite the advances that we have made in our shrinking world, we are not yet able to fully embrace the scholarship that is done outside our native lands. Though there are clear exceptions, it is often true that the majority of the references that appear in a given manuscript cite work that was done in the native country of the author. This is not all bad for it makes us realize that problems and issues are amazingly similar from one country to another and that lines of inquiry somehow take similar, albeit independent, courses. There is also some interesting and pertinent triangulation that can occur. You will note an example in this issue in regard to the design and problem solving process as you read the articles by Gustafson, Rowell, and Guilbert on the one hand, and Williams on the other. In fact, the design and problem solving theme seems to run, to an extent, through all of the articles in this issue even though it was not planned that way. The editorial by Cajas lends a science perspective to design. But is it really a science perspective? What exactly is a science perspective? How high are the walls in our minds around science and other disciplines? How high are the walls that those from other disciplines build in front of us?

The value of reinventing the wheel aside, it seems that we could move ahead more quickly if we would let the world become smaller and used the work that others have already completed. I am confident that this will happen as we fully develop our world-wide electronic library of the future and we regularly meet with one another internationally through the wonders of technology. I think the words of the song and its melody are beginning to have a new, exciting meaning.

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Articles

Elementary Children's Awareness of Strategies for Testing Structural Strength: A Three Year Study

Brenda J. Gustafson, Patricia M. Rowell and Sandra M. Guilbert

Introduction

In recent years there has been a trend towards including design technology in elementary school programs either as a separate subject area or as an addition to some existing science program. Design technology study is seen as a means for children to develop procedural and conceptual knowledge of devices created to fulfill a human need.

In Alberta, Canada a new *Elementary Science Program* (Alberta Education, 1996) was mandated for use in September 1996. One feature of this new program was the inclusion of a *Problem Solving Through Technology* topic at each of the six grade levels. *Problem Solving Through Technology* topics were intended to promote children's development of skills and knowledge related to design technology (Rowell, Gustafson, & Guilbert, 1999 a, b).

The three year research project from which this paper is written commenced in September 1995; one year prior to the mandated implementation of a new *Elementary Science Program* (Alberta Education, 1996). In this three year project, we asked elementary children to respond to *Awareness of Technology Surveys,* interviewed teachers, administrators and engineers, conducted case studies in classrooms, and involved children in performance based assessments related to the design technology topics. The scope and nature of this three-year research project is described in detail in previous publications (Gustafson, Rowell, & Rose, 1999; Rowell & Gustafson, 1998).

Research Questions

In the research reported in this paper, we focus on one question from the *Awareness of Technology Survey* that was administered in Study Year One (September, 1995–June, 1996) prior to the implementation of the new Alberta elementary science program. A revised version of this same survey question was re-administered to children in Study Year Three after they had participated

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in formal classroom experiences in Study Year Two related to the *Problem Solving Through Technology* topics. The survey question, named Jan's and Bob's Bridges, was designed to explore elementary children's awareness of strategies for testing the structural strength of bridges pictured in the survey. Analysis of the children's responses to this survey question allowed discussion of the following research questions:

1. What is the nature of children's ideas about testing structural strength?
2. How do children's perceptions of testing strategies change over time?
3. Do young children's survey responses differ from those offered by older children?
4. Are there any gender related differences between survey responses?

Related Literature

The theoretical underpinnings of this research are primarily drawn from constructivist learning theory and research into the nature and development of children's design technology problem solving skills.

Ideas from Constructivist Learning Theory

Constructivists view learning as a complicated endeavor influenced by the learner's existing ideas, the learner's willingness to engage intellectually in the task at hand, the socio-cultural context, and the teacher's pedagogical practice (Appleton, 1997; Driver, 1989; Harlen & Jelly, 1989; Osborne & Freyberg, 1985). Constructivists believe that prior to formal classroom instruction children possess existing ideas that are sensible (to the children), strongly held and constructed from a number of sources and experiences (Osborne & Freyberg, 1985). These existing ideas may prove helpful or unhelpful when children encounter new ideas in the classroom and draw upon existing knowledge to make sense of the encounter (Appleton, 1997). In addition to recognizing the importance of existing knowledge, constructivists also lend support to the observation that children may participate in common classroom experiences and subsequently display a variety of interpretations of those experiences (Appleton, 1997). The complex ways in which children use existing ideas to make sense of new situations and move towards some understanding or solution can help account for the variety and nature of children's ideas.

Ideas from Design Technology Research

Much design technology research has focussed on characterizing what children do to solve problems and arranging these actions into design technology problem solving models (Bottrill, 1995; Johnsey, 1995, 1997; Layton, 1993; McCormick, 1996; Roden, 1997). Various terms have been used to describe children's problem solving actions. They include processes, procedures, procedural skills, facets of performance, facets of capability, problem solving skills, problems solving processes, and thinking processes (Bottrill, 1995; Custer, 1995; Johnsey, 1997; Kimbell, Stables, & Green, 1996). Regardless of the label given to these actions, researchers tend to produce lists of actions or skills, sometimes arranged into problem solving models, which can include designing, making, trouble-shooting, repairing, inventing, testing, and evaluating. These problem solving models can then be used to direct teaching practice, assess children, and influence program development.

A skill commonly appearing in problem solving models and considered to be one facet of technological capability is evaluating or testing a product (Kimbell, 1994). In the research presented in the paper, we have tended to view evaluating and testing as closely linked and capable of occurring concurrently (Anning, 1994; Anning, Jenkins, & Whitelaw, 1996; Bottrill, 1995). Other researchers have distinguished between the two while emphasizing that both can occur during and at the end of an activity (Kimbell, Stables, & Green, 1996). In reviewing a range of problem solving models, Johnsey (1995) showed that evaluating could involve: judging a solution against some specifications; identifying judging criteria; evaluating the effectiveness of a solution; critically appraising a solution inside the head; considering design ideas as they develop; appraising the efficacy of design activity, or; accepting or rejecting a solution. Testing could involve: testing the performance of a product; conducting trials; testing an outcome; validating and judging inside the head together with testing; testing a solution, or; assessing the effectiveness of a product (Johnsey, 1995). Evaluating and testing, therefore, do not appear mutually exclusive. At times these skills can blend together as children judge whether a device has met the original identified need, whether it exhibited appropriate resource use, and whether it made an impact beyond the purpose for which it was designed (Anning, Jenkins, & Whitelaw, 1996; Kimbell, Stables, & Green, 1996; Tickle, 1990).

Evaluating or testing can occur during the process of reaching an effective solution and additionally involve summative evaluation of product success against design criteria (Bottrill, 1995; Kimbell, Stables, & Green, 1996). In classroom situations, evaluating or testing allows children to reflect on the developing design and think about design strengths and weaknesses once it has been completed (Kimbell, Stables, & Green, 1996). In the present study, we explore testing or evaluation strategies that would likely occur during summative evaluation of a structure.

Age and Gender Issues in Design Technology

Researchers have observed that young children frequently display a reluctance to perform summative evaluation or testing and may have difficulty performing the cognitive tasks necessary for evaluation. Anning (1994) observed that teachers of young children found it unrealistic to expect children to perform summative evaluation. Children viewed this evaluation as ‘doing it again’ and were reluctant to engage in this task. Evaluation was much more useful if it “permeated the whole iterative cycle of designing and making” (Anning, 1994, p. 174). Other researchers have agreed that Key Stage 1 (ages 5-7) children prefer to respond to problems on an ongoing basis and see less need to perform summative evaluation on their finished products (Kimbell, Stables, & Green, 1996).

Product evaluation and testing involves complex cognitive demands. Kimbell (1994) describes these demands as encompassing an understanding of materials, tools, and processes then using this knowledge to make a product and evaluate it critically against the needs of the user. This can be a daunting task for young children. Other researchers observe that young children can show a reluctance to test or evaluate their work because they lack the mental models against which to make informed judgements or resist the requirement to think deeply or are unaware of appropriate evaluation criteria (Anning, 1994; Anning, Jenkins & Whitelaw, 1996). Clearly, researchers perceive differences between evaluation conducted by children of different age groups. Kimbell (1994) warns, however, that caution should be used when assigning criteria of capability based on children's ages. Perceived capability in testing or evaluating could be influenced by any number of factors known to play a role in children's understanding of constructing.

Fewer studies have been conducted on gender differences in design technology (Kimbell, Stables, & Green, 1996; Ross & Brown, 1993). An observation pertinent to the present study is that in general, girls do better than boys in the more reflective areas of design technology work. An example of these more reflective tasks includes testing and evaluating products in terms of their performance and fit with evaluative criteria.

Study Framework

In this section, we provide a brief overview of the Alberta program followed by information about study methodology**.**

Alberta Program

As mentioned earlier, in September 1996 a new *Alberta Elementary Science Program* (1996) was mandated for use in Alberta schools. The program featured four *Science Inquiry* (SI) topics and one *Problem Solving Through Technology* (PST) topic at each of the six grade levels. The *Problem Solving Through Technology* topics were intended to show links between science and technology through allowing children to participate in design technology activities created to promote technological problem solving capability and conceptual knowledge. In each grade level, a *Problem Solving Through Technology* problem solving model was outlined which arranged technological problem solving skills under three headings: Focus; Explore and Investigate, and Reflect and Interpret. A *Science Inquiry* (SI) problem solving model in which skills were outlined under the same three headings was also included in the program. These models were followed by the topics for the grade and a list of General and Specific Learner Expectations (GLEs and SLEs) written in behavioral terms describing activities related to the topics.

In Grade One, the PST model provides no specific mention of evaluating or testing. Instead, the *Building Things* topic asks children to select materials and construct objects such as buildings, furniture, vehicles, and wind and water related artifacts. These building activities quite naturally involve the ongoing evaluation of materials and methods of fastening despite the lack of acknowledgement of these skills in the problem solving model. Grade Two focuses on a

Buoyancy and Boats topic which promotes building and testing a variety of watercraft, testing that leads to modifying a watercraft and evaluating the appropriateness of various materials. The PST model at this grade level reiterates that children should “identify steps followed in constructing an object and in testing to see if it works” (Alberta Education, 1996, p. B6). *Building With a Variety of Materials* is the Grade Three PST topic frequently taught in conjunction with a *Testing Materials and Designs* science inquiry topic. These two topics ask children not only to construct and test structures that span gaps, but also to conduct tests to show how materials, shapes, and methods of joining effect the strength of structures. The Grade Four SI model mentions that children should “carry out, with guidance, procedures that comprise a fair test” (Alberta Education, 1996, p. B17). The PST model states that children will “identify steps followed in completing the task and in testing the product” and “evaluate the product based on a given set of questions or criteria (Alberta Education, 1996, p. B17, B18). Grade Four children participate in a *Building Devices and Vehicles That Move* topic which further requires them to explore and evaluate design variations of mechanical devices and models. In Grade Five, the SI model again mentions the importance of carrying out fair tests and the PST model asks children to “evaluate a design or product, based on a given set of questions or criteria” (Alberta Education, 1996, p. B24). As Grade Five children work on *Mechanisms Using Electricity,* they use ongoing evaluation to construct electrical devices such as motion detectors and burglar alarms. Fair testing is again emphasized in Grade Six with children expected to evaluate procedures used and products constructed. The topic *Flight* provides a context in which children can build and test a number of flying devices such as designs for parachutes, gliders and propellers.

Clearly, the Alberta program provides opportunities for children to work in a number of contexts to develop evaluating and testing skills that would promote the development of technological capability. What is less clear is how Alberta teachers operationalized these program expectations during Study Year Two of this research project.

In order to provide insight into Study Year Two instruction, we conducted case studies in six elementary classrooms (Rowell & Gustafson, 1998). Many of the children who responded to the *Awareness of Technology Surveys* were enrolled in these classrooms. Case studies showed most teachers struggled to understand the conceptual underpinnings of the design technology topics, were unfamiliar with the discourse of technological problem solving, tended to interpret technological problem solving models as similar to science inquiry models, and received little professional support for the development of necessary skills and understandings. Despite these challenges, generally teachers were enthusiastic about the design technology topics and the potential these topics held for extending children’s understanding of technology and science.

Study Methodology

Instrument

The instrument used was named the *Awareness of Technology Survey* and featured questions intended to explore children's characterization of technology and knowledge of skills and concepts related to the Alberta program. Each of the six grade levels featured a different selection of questions related to program expectations with some questions, such as Jan's and Bob's Bridges, repeated at each grade level.

Awareness of Technology Survey questions were either created by the authors or patterned after similar questions posed in previous studies by other researchers (Aikenhead, 1988; CoenenVan Den Bergh, 1987; DES, 1992; Gadd & Morton, 1992 a, b; Harrison & Ryan, 1990; Rennie, 1987; Rennie, Treagust, & Kinnear, 1992; Symington, 1987). Working copies of questions were sent to provincial government personnel familiar with the new program who had experience with student assessment and test development. Comments from these consults were used to improve question structure and provide validation of survey questions with respect to the new program.

Piloting

The *Awareness of Technology Survey* was piloted with a group of 140 children in grades one through six (ages 5-12). Grade One children who had yet to develop extensive reading skills had questions read to them as a whole group; this strategy was used despite the fact that the Grade One version of the survey featured little writing. Children's oral questions and advice as well as teacher comments were noted. Children's written survey responses were analyzed by study authors to check whether they addressed the original intent of the questions and revisions were made to the questions. This piloting experience allowed authors to construct the *Awareness of Technology Survey* used in Study Year One. A revised version of this same survey which eliminated some Study Year One questions and asked children to elaborate more on remaining questions was used in Study Year Three.

Selecting the Children and Administering the Survey

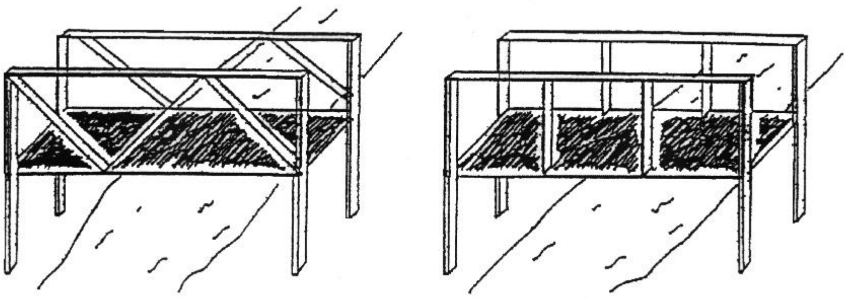
The *Awareness of Technology Survey* was administered in cooperation with a rural school system located adjacent to a large urban area. Classrooms and teachers were selected by the school system's Program Facilitator, who was careful to involve children from a variety of schools and grade levels. In Study Year One, 334 children (180 male, 154 female) from all six grade levels completed the survey. In order to assist Grade One children with reading the survey, a research assistant read the survey to each child and assisted with writing down the children's verbal comments. Teachers in other grade levels were asked to assist any children assigned to their classrooms who encountered reading difficulties.

In Study Year Three, children who had completed the Jan's and Bob's Bridges survey question in Study Year One were located and the revised version of the same question was asked of them. Those students who had been enrolled in Grade 6 in Study Year One were excluded from Study Year Three data collection since they would now be in Grade 7 (Junior High School). They would therefore not have participated in experiences related to the *Problem Solving Through Technology* topics in the elementary science program.

Study Focus

This research study explored strategies for testing structural strength proposed by elementary children before and after formal classroom instruction in *Problem Solving Through Technology* topics. Specifically, this research reports on children's responses to the Jan's and Bob's Bridges survey question that focused on how children might test the structural strength of two bridges which were presented to them in the form of illustrations, as shown in Figure 1.

JAN AND BOB EACH BUILT A BRIDGE ACROSS A SMALL STREAM



JAN'S BRIDGE BOB'S BRIDGE

Figure 1. Illustrations of Jan's and Bob's Bridges as presented in the study.

The questions asked of the children at the two levels of the study are presented in Table 1.

The focus was on 167 elementary children (83 male; 84 female) who completed this survey question in both Study Years One and Three (see Table 2). In Study Year One, these children were enrolled in Grades 1-5 (ages 5-11) and in Study Year Three were in Grades 3-7 (ages 8-14). Examining the same population in both years (while keeping in mind the unequal numbers of subjects between grades) allows judgements to be made about the degree to which participation in classroom activities in Study Year Two might have promoted children's testing and evaluation strategies.

Table 1
Questions Asked of Children at Study Year One and Study Year Three

Study Year One	Study Year Three
Circle the strongest bridge.	Circle the strongest bridge.
How could you find out if your answer is correct?	Why do you think this bridge is the strongest?
	What would you do to find out if your answer is correct?

Results

In Study Years One and Three, children were asked to decide whether they thought Jan’s or Bob’s bridge was stronger and then propose a testing strategy which would confirm or possibly disprove their decision. Children’s responses about testing strategies were read repeatedly and were ordered into five categories in terms of their usefulness for understanding the problem and components of fair testing. The children’s responses ranged from indicating why the bridge was strong to suggestions involving elements of fair testing. The five categories are shown in Table 3.

Children in Category 1 could be viewed as having misread the question as they focused on describing *why* the bridge they circled was stronger than the other bridge rather than *how* to test for bridge strength. Some survey responses tended to focus on the obvious differences between the bridge railings and children variously judged either slanted or vertical railings as key to structural strength. For example, some children wrote:

- Because [up and down railings] can hold it up better.
- Because this one has squares and the other has diamond shapes.
- The posts go up and down.

Other children noticed Jan’s bridge had three diagonal railings while Bob’s had two vertical railings but it remained unclear how this would affect bridge strength.

- This one has more sticks [Jan’s].
- This one [Bob’s] has less sticks so it will hold people.

Some of the younger children in Category 1 seemed to have difficulty interpreting the three-dimensional picture. Some argued that their selected bridge was stronger because the wood was thicker or that one bridge was bigger than the other bridge. Although Category 1 responses did not address the issue of testing, they still provided some insight into children’s notions of structural strength. Clearly, in trying to judge structural strength, some children thought that the orientation of structural components was critical while others believed the amount of materials used impacted on structural strength. Although component orientation is a key idea underpinning structural strength, the issue of material amount is more contentious. Adding more materials can, in some situations, increase the strength of the structure. But other factors, such as the type of material, how it is joined to the structure, and the way it is oriented within the structure, could all potentially influence whether additional materials do increase strength.

Table 2
Descriptive Statistics

Study Year 1 Grade	Gender	Response Category Mean	Standard Deviation	*N*
1	Male	1.48	.87	21
	Female	1.25	.44	24
	Total	1.36	.68	45
2	Male	1.77	1.24	13
	Female	1.73	1.10	11
	Total	1.75	1.15	24
3	Male	1.29	.47	17
	Female	2.05	.91	19
	Total	1.69	.82	36
4	Male	2.09	1.51	11
	Female	2.00	1.41	17
	Total	2.04	1.43	28
5	Male	2.20	1.01	20
	Female	3.43	1.34	14
	Total	2.71	1.29	34
Total	Male	1.74	1.05	82
	Female	2.00	1.24	85
	Total	1.87	1.16	167

Study Year 3 Grade	Gender	Response Category Mean	Standard Deviation	*N*
3	Male	1.95	1.07	21
	Female	1.96	1.00	24
	Total	1.96	1.02	45
4	Male	2.54	.97	13
	Female	2.45	.82	11
	Total	2.50	.88	24
5	Male	2.88	1.11	17
	Female	2.68	1.20	19
	Total	2.78	1.15	36
6	Male	3.00	1.41	11
	Female	3.12	1.50	17
	Total	3.07	1.44	28
7	Male	2.70	1.34	20
	Female	3.93	1.38	14
	Total	3.21	1.47	34
Total	Male	2.56	1.22	82
	Female	2.74	1.36	85
	Total	2.65	1.29	167

Table 3
Categories of Children's Responses

Category	Description
1	Indicated *why* the bridge was strong; but not *how* to test the bridge
2	Concept of testing was weakly expressed (e.g., Build it; Test it.)
3	Testing concept developed, but fairness lacking (e.g., Add weights; Put toys on it; Shake it.)
4	A fair test but lacking all the items (exact same test for each bridge)
5	A fair test including weights and a measurement decision (e.g., addition of the element of measurement: how much weight could be added until one broke)

Category 2 responses showed an awareness of testing but children seemed unsure about exactly what would constitute fair testing strategies. Some simply advised that one could camp, drive, walk or jump on the selected bridge, hit it with a hammer, kick it, or build it. Some children wrote:

- I would build the bridge and put pressure on the railing.
- Walking across it.
- I would put a small toy car on it.

No mention was made of comparing the two bridges or of specific criteria used to perform the test. Be that as it may, the children offered ideas that could form the beginning of good testing ideas.

The third response category included children who showed more development of testing strategies than the previous category in that some of them acknowledged the necessity of comparing the bridges, while others provided a few more details about the testing strategy. For example, some children wrote:

- Put some things on each of the bridges.
- Rock them back and forth.
- Walk across each bridge.
- I would find out if it was correct by putting something heavy on both of the bridges.

Through these responses children showed they realized that comparative testing was needed in order to judge which bridge was stronger. However, some did not include many details. Others did not mention continuing the test until some conclusive observations could be seen.

Category 4 included children who wrote about a fair test and the necessity to continue that test until some conclusion could be arrived at, but were still in need of clarifying some of the testing details. For example, children wrote:

- You could build them and test it with weight and see whose bridge falls down first.
- You could get lots of people to stand on each on and see which holds better.
- I would find out by tapping it a little bit and see which ones collapse.

Category 4 contained useful ideas simply in need of a few more details. The first child quoted above could be asked to clarify the manner in which the weights would be added to the bridges, the second child asked how people would be ordered onto the bridges, and the third child asked to outline the details of the tapping test. These added details would show the details of the fair testing procedure contained in the responses.

Children in Category 5 provided impressive fair testing ideas that included details about how to compare the relative strength of each bridge. One child suggested that, "…you could put something [equal to] the weight of an averaged sized eleven year old child and put it on to see if it will brake or not then if they don't breke try going hever" [sic]. Another child responded in a similar vein that "you could put weights on the bridges and keep on putting weights on until one of the bridges broke." These responses show the children in this category had an understanding of fair testing similar to the expectations found by the Grade Five level of the Alberta program. The variety of written responses to the survey question provide insights into the first research question listed at the beginning of this paper.

Statistical analysis of children's coded responses was used to provide answers to the remaining three research questions and to help judge differences between study years, grades, and gender. In this way, it was hoped that some insight might be discovered of how children's perceptions of testing strategies might have changed over time, how younger children's answers compared to older children's answers, and whether there were any significant differences between boys' and girls' responses. Significant differences between these variables could provide some understanding of how population samples performed as well as the possible efficacy of Study Year Two instruction.

A 2X2 ANOVA using a repeated measures procedure was applied to Study Years One and Three data to examine the differences in students' performance on the Jan's and Bob's Bridges survey question. The obtained scores were assumed to be independent and normally distributed within each treatment level. The computed Greenhouse-Geiser epsilon value was 1.000 showing that the condition of sphericity in the repeated measures procedure was met. The results of the ANOVA are reported in Table 4.

Table 4
ANOVA Between Study Years One and Three

Test	SS	*df*	MS	*F*	*p*
Year	49.119	1	49.119	40.545	.000
Year*Grade	4.773	4	1.193	.985	.418
Year*Gender	.243	1	.243	.201	.655
Year*Grade*Gender	4.273	4	1.068	.882	.476
Error (YEAR)	190.199	157	1.211		

An overall significant difference (p<.05) in students' performance on the Jan's and Bob's Bridges survey question between Study Years One and Three (F (1, 157) = 40.545) was found. Tests of interactions (Year X Grade; Year X

Gender; and Year X Grade X Gender) indicate that the difference between the two Study Years was uniform across the five grade levels and was not influenced by the respondents' gender.

The ANOVA of between-subject effects (see Table 5) reveals a significant interaction between gender and grade. This means that boys and girls performed differently to the survey question depending on grade level (*F* (4,157) = 4.02). In particular, when all boys in the study are compared to all girls in the study (study years combined), boys outperformed girls in the lower grades while girls outperformed boys in the higher grades (see Table 6). Table 5 also shows a significant grade level effect (*F* (4,157) = 15.72) which means students in different grade levels performed differently (see Table 6 for details between grades). To illustrate, Bonferroni post hoc tests for between-subject effects show significant differences in mean performance across two years of study between Grades 1 and 4 and between Grades 1 and 5 (*t* (5,157) = -3.58, and *t* (5,157) = -4.91 respectively). Table 5 also features a marginal significant overall gender effect, meaning that when boys and girls in the two years of the study are combined, the genders perform differently. This marginal effect was further examined through planned post hoc multiple comparisons, which revealed that boys in Grades 4 and 5 together performed differently across the two years of study when compared to girls in the corresponding grades (*t* (2,157) = -2.73).

Table 5
ANOVA of Between-Subjects Effects

Test	SS	*df*	MS	*F*	*p*
Intercept	1690.35	1	1690.35	1322.47	.000
Grade	80.38	4	20.10	15.72	.000
Gender	5.69	1	5.69	4.45	.036
Grade*Gender	20.57	4	5.14	4.02	.004
Error	172.52	157	1.10		

Table 6
Table of Means: Mean Performances Across Gender and Grade (Study Years One and Three Combined)

Gender	Grade 1(3)	Grade 2(4)	Grade 3(5)	Grade 4(6)	Grade 5(7)	Total
Male	1.715	2.155	2.085	2.545	2.45	2.15
	N=21	*N*=13	*N*=12	*N*=11	*N*=20	*N*=82
Female	1.60	2.09	2.365	2.56	3.18	2.37
	N=24	*N*=11	*N*=18	*N*=12	*N*=14	*N*=85
Total	1.66	2.082	2.225	2.553	2.815	
	N=45	*N*=24	*N*=36	*N*=28	*N*=34	*N*=167

Bonferroni post hoc tests were conducted to examine differences in students' performances on the survey question over time at each grade level (see Table 7). The Bonferroni procedure was used because of its conceptual simplicity, flexibility, and ability to control Type 1 error when families of contexts are tested. The results indicated that the difference in performance on the survey question administered in Study Years One and Three was statistically significant (*p*<.05) for students who were in Grades 3 and 4 in Study Year One then Grades 5 and 6 in Study Year Three.

Table 7
Bonferroni Post Hoc Tests

Grade	Mean Difference	Bonferroni *t*((5,157)
1-3	-.60	2.59
2-4	-.75	2.36
3-5	-1.09	4.20*
4-6	-1.03	3.50*
5-7	-.50	1.87

**p*<.05

Discussion

The most useful part of this study lies in the range of survey responses offered by the children and the insight this provides into future classroom practice. Clearly, children hold a variety of ideas about how to test structural strength even before formal classroom instruction in this design technology skill. These ideas likely arise from prior experiences encountered during everyday life. The frequency of responses of the children among the five response categories developed for the study, however, revealed that children in all grade levels are in need of further assistance.

Most responses in Study Years One and Three tended to fall into Categories 1-3 despite statistical analysis showing an overall significant difference between the two study years. Category 1 included ideas about why a bridge was stronger while Categories 2 and 3 included a beginning awareness of testing strategies. These ideas about strength and testing are potentially useful but still in need of further refinement. A productive use of classroom time would involve exploring children’s existing ideas about testing strategies and helping children grow towards recognizing how a fair comparison between two structures would allow a more critical appraisal of the design.

Another important idea following from the response categories involves the ordering of the categories. Through ordering children’s responses we only sought to provide an interpretive framework for this research study. Suggesting that children’s responses indicate sequential stages of understanding fair testing through which children progress is not supported by this study. Instead, we do not rule out that children could show many unanticipated routes and frequent reversals of thinking before arriving at a full understanding of fair testing. A similar argument questioning the sequential ordering of problem solving skills could also be applied to technological problem solving models depicted in school programs. Johnsey (1997) has argued that children tend to employ problem solving skills in a fairly random way and that skills are naturally intermixed as children work towards solutions. Others describe technological problem solving as a messy and somewhat internally chaotic experience bearing little resemblance to the stage models appearing in literature (Ridgway & Passey, 1992; Rowell & Gustafson, 1998). Clearly, problem solving models listing skills arranged in some sequence or series of stages may not provide an accurate picture of how children tackle classroom problem solving. Further, describing individual skill development as being comprised of some progressive sequence of thinking might be equally misguided.

A second focus of this study was on the possible influence of experiences from Study Year Two on the children's responses over time. Study Year Two featured opportunities for children to participate in design technology units that should have included learning about evaluating and testing. As mentioned earlier, design technology topics in the Alberta program varied in their emphasis on testing and evaluating and featured the development of these skills within a number of different contexts. Also, teachers faced with implementing these topics in Study Year Two received little professional support, were inexperienced with concepts related to structural strength and skills such as testing, and found it challenging to interpret and teach the new program.

Some researchers maintain that problem solving is a domain specific activity and that expertise in some skill in one context does not necessarily mean the skill can be transferred successfully to some other context (McCormick, Hennessy, & Murphy, 1993; McCormick, Murphy, Hennessy, & Davidson, 1996). When this hypothesis is applied to the Alberta program, it means that children would need to revisit fair testing each year as they encountered different contexts within the program. Teachers would have to be cautious in assuming that children could use fair testing experiences to interpret contexts from one grade to another. In this research study, only children participating in testing bridges in Study Year Two (children enrolled in Grade 2 in Study Year One) would have encountered a classroom building context similar to the survey question and thus would be expected to show the greatest improvement over the course of the study. This was not supported by statistical analysis. Instead, Table 7 showed that when individual grades are examined, only children who were in Grades 3 and 4 in Study Year One showed a significant change in Study Year Three. In Study Year Two, children formerly in Grade 3 would have participated in the *Building Devices and Vehicles That Move* topic while children formerly in Grade 4 would have experienced the *Mechanisms Using Electricity* topic. Both of these program topics involve extensive experiences with constructing devices and performing fair tests but in contexts different from that displayed in the survey question. Future research on how particular contexts may or may not assist children to develop evaluating and testing skills over time would be useful.

Other researchers have observed that some skills can be generalized to other contexts far better than others (Ridgway & Passey, 1992). They have speculated that time taken to learn some skills, the degree to which a task may be contextualized, and the way in which each child has structured existing knowledge may all help account for variations in skill generalizability (Ridgway & Passey, 1992). We would tend to agree with this more complex interpretation of skill generalizability while adding that in this research study, the issue was further complicated by the lack of professional support for teachers. This lack of support influenced teachers' understanding of the program and consequently affected the degree to which children could structure an understanding of program components.

Results addressing study questions about age and gender differences are more difficult to interpret. Results show that in general, younger children responded to the survey question slightly differently from older children. In Study Years One and Three, younger children tended to provide ideas about testing that were in the first three categories. Older children showed a slightly greater inclination for more detailed answers. In regard to gender differences, results show that depending on the grade, either the boys or the girls could be judged as outperforming the other gender, but these distinctions were not greatly significant. We believe that study limitations can help account for these more indistinct results. One limitation would involve contextual variables associated with the survey question. Anning (1994) warned that contextual variables will affect children's responses and the type of question, the context of the question, support for reading the question, and children's previous experiences with bridges can affect their answers. Another limitation is the variability in Study Year Two experiences. If skill capability is influenced by context, teaching practice, and teacher preparedness, then the variety of learning contexts in which evaluating and testing were developed in Study Year Two might well have influenced study results. A third limitation might lie in using an atomized assessment to make judgements about children's capabilities. Kimbell (1992) cautions against the exclusive use of atomized assessments and advises that if atomized assessments are used, they should be balanced with whole judgements derived from children's performance on a variety of tasks.

Study results, as well as limitations to this study, help reveal productive areas for future research. In order to assist with characterizing children's testing strategies for any one age group or gender, children could be observed as they participate in a number of similar contexts that involve testing or evaluating. In this way, a more extensive profile of testing strategies might emerge which could show more distinct trends in children's thinking. Information about children's thinking would help inform the design and content of school technology programs. Further, children could be observed as they participate in a number of different contexts; children's work in these contexts could then be compared in order to help answer in what ways context contributes to skill development. Information about contexts could influence the nature of practical activities recommended for inclusion in school programs and teachers' selection of classroom activities. Finally, the study could be repeated after teachers had gained more expertise with teaching design technology. Perhaps when teachers had the support and time to become familiar with technological problems solving, concepts and discourse, more insight could be gained into how participation in school technology programs influences children's skill development.

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The Role of Experience in Learning: Giving Meaning and Authenticity to the Learning Process in Schools

Ronald E. Hansen

Recent studies of technological education teachers in Germany, England, and Canada indicate that the socialization process these teachers undergo while adjusting to the profession is a difficult one (Hansen, 1998). Among other things, the adjustment is complicated by a preference for learning which is out of harmony with the teaching and learning strategies employed by teachers from other subject areas in the secondary school curriculum. The preconceptions and tendencies these technology teachers bring to the profession reveals a strong bias towards experience as a framework for learning. In Ontario, Canada, technology teachers are required to have a minimum of five years work experience in their technological specialization before qualifying for teacher education. Most of these teacher candidates entering the profession have ten to twelve years of such experience. They have already been socialized into a business and industry culture which preaches the virtues of experience over rote learning. Meanwhile the Ontario secondary schools in which these technology teachers work tend to devalue courses with experiential learning traditions.

The purpose of this manuscript is to explicate what constitutes an experiential frame of reference for learning, for these adult professionals and for people generally. How effective is learning when actions, project work, and personal experience (the non-discursive world) transcend or precede signs and symbols (the discursive world)? What are the benefits to students? What can be learned from technology teachers about the value of experience? What are the implications of this way of learning for the secondary school system and the curriculum as we know it?

The Nature of Experiential Learning

Understanding how people learn is something that has both propelled and detained education scholarship at the same time. For decades, educational psychologists have studied the learning process. They concluded that learning is equated to a change in behavior. Beyond this important conviction, very little consensus about what characterizes the learning process exists and there is no common understanding. Dewey's essays are often credited with most closely defining the learning process among youth. Yet his writings are not considered

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definitive. It is amusing and perplexing that the state of scholarship in education associated with understanding how people learn is so undistinguished. What is so illusive about this phenomenon? What is it about the phenomenon or the scholarship that serves it which makes the concept a difficult one to describe succinctly? Boud's (1989) work [cited in Weil & McGill] places the learning process into a broader perspective. His views may represent a fresh starting point for re-casting or re-framing how educators, especially technology educators, think about learning.

> Although experiential, or experience-based learning can be regarded as the earliest approach to learning for the human race, the significance and potential of it has not been fully recognized until relatively recently. In the formal education system it has tended to be developed and regarded as somehow fundamentally inferior to those organized forms of knowledge which have been constructed as subjects or disciplines. The practical and the applied do not tend to have the same status in educational institutions as the academic and the abstract. (p. xi)

Interestingly, scholars from outside of youth education often have a more sanguine contribution to make in defining how people learn. Adult education scholars (Chickering, 1977; Jarvis, 1987; Keeton, 1976; Kolb, 1993; Merriam & Clark, 1993; Rogers, 1951), for example, have found it constructive to document the learning process for adults as experiential. What these authors do is provide alternative ways of looking at the question of how people learn, resulting in a productive view of the learning process among humans, both young and old, about which there is a reasonable degree of consensus.

Kolb (1984) argued that defining learning in terms of the change in behavior is limiting and it poorly characterizes the learning process. Kolb defined learning as a human adaptation process. "It is a process whereby knowledge is created through the transformation of experience" (p. 38). He cited Lewin's (1951) work as the empirical evidence for supporting a learning cycle theory that begins with the experiences of the learner. Lewin's formula for learning describes human behavior as a function of a person and the environment [$B=f(p, E)$]. Learning takes place, according to Lewin, when a learner (person) interacts with, or is stimulated by, an environment. Others adopt the same 'human adaptation process' explanation for learning, but cast it in different ways. Jarvis (1987), for example, put it this way: "…there is no meaning in a given situation until we relate our own experiences to it" (p. 164). Experience plays a key role in the process. Rogers has been quite outspoken about the learning process, especially the role of a teacher in that process. He believes no one learns anything of significance from someone else. Instead, learning takes place when a learner is intrinsically motivated to learn and undertakes to learn something on his/her own. This sentiment is echoed by Albert Einstein who was quoted as saying: "I never teach my pupils; I only attempt to provide the conditions in which they can learn" [cited in Walter & Marks, 1981, p. 1]. In short, there appears to be more clarity and conviction about what constitutes learning among people outside of the formal education field than in it.

To reach their conclusions about how people learn, these scholars make reference to quantitative and qualitative studies with human subjects. They follow the canons of science to clarify and verify what they believe to be true. A contrasting method for exploring the learning phenomenon is to trust in one's own experience. Beginning with Boud's broader perspective of how people learn, the following analysis attempts to do this from first principles. It represents an attempt to trust experience in apposition to, or in contrast with, the rules of scientific inquiry. The remainder of the paper draws on two more pragmatic forms of inquiry for its analysis. Following a review of some recent literature on what constitutes learning, conceptual analysis and comparative analysis will be used to explicate the essence of experiential learning.

Learning As An Active Versus Passive Process

Traditional pedagogy tends to assume the acquisition of knowledge and understanding by the mind is a passive exercise. Psychological research and theory perpetuates this tradition by dividing the person into body and mind, into active and passive processes. Insufficient attention is paid to combinations of these categories. The result is a gap between what experience tells us about how we learn and what the experts tell us. "Thought and action tend to have been separated, thinking and understanding to have been seen as abstract and general, therefore as teachable in abstract isolation from practical experience. In contrast, practical competence has often been spoken of as though it were just a matter of doing; skill is then taken to mean a combination of thoughtless behaviour habits, inculcatable through simple practice" (Tomlinson & Kilner, 1992). The momentum associated with this view is so deeply imbedded in teacher education methods and curriculum that it has seldom been challenged, until recently that is.

Harre and Gillett (1994) in a book entitled *The Discursive Mind* challenged the prevailing view of how people retain what they learn. In a chapter entitled, "The Discursive Origins of the Sense of Self," the authors suggested that learning a language, i.e., learning signs and symbols, does not give human beings a sense of physical location. "It is the learning of perceptual and motor skills that is responsible for that" (p. 111). Human beings, they suggest, live in two worlds:

> One world is essentially discursive in character, that is, it is a world of signs and symbols subject to normative constraints. [The second is the material or physical world]. There are two main kinds of skills that are often brought into play together and in complementary ways [within these two worlds]. There are manual skills, those we use to manipulate material stuff, and there are discursive skills, those we use in our symbolic interactions. The world of symbols is organized by the norms and conventions of correct symbol use. The other world in which we live, the physical or material world, is structured by causal processes. Our language is our main means for

> managing in the world of symbols, our hands and brains are in the material world. (pp. 99-100)

This analysis may help explain the experiential frame of reference preferred by technological education teachers. These teachers have lived and worked extensively in the material world developing their problem solving and manual skills. They often become socialized into a way of learning that is different from that used in the schools. In some respects learning and practicing technology are synonymous activities to them. Human development in its fullest sense (a balance of the two worlds Harre and Gillett describe) requires that people learn to function effectively in the discursive world but as a complement to the material world, rather than in opposition to it or apart from it. These technology teachers may, in fact, be applying a learning methodology which has implications for understanding how people learn but which is overlooked in the educational sciences.

The ramifications of this observation are amusing and perplexing at the same time. What would a curriculum which blends the discursive and non-discursive worlds look like? The sense of self that Harre and Gillett described brings the role of the teacher and the role of experience in learning into clearer focus. Their position that the sense of self and learning/development are unified through experience is intriguing:

> The discursive thesis is that to experience oneself as having a location in a manifold of places and in relation to others is a necessary condition for being able to use and to understand indexical expressions. How does it come about that these senses of unique location are the salient features of selfhood? We do not believe that learning a language is what is responsible for our having the sense of physical location. It is the learning of perceptual and motor skills that is responsible for that. But it is expressed in the indexical grammar of I. We think that the sense of agenetic position, the sense that one is the agent of one's actions and responsible to others for them, is something that we acquire through learning the language and cultural conventions for the assignment of responsibility. These aspects of the sense of the self—physical location, temporal continuity, and agency—have different origins but they come together in the grammar. According to Vygotsky, the learning of manual skills is just as much a necessary condition for acquiring a sense of self as the learning of verbal skills. We believe that perception is a kind of manual skill. The ability to use your eyes is a bit like the ability to use your hands. In living our lives as members of a community that inhabits physical space and time, and assesses each of its members for reliability, these centerings come together. (p. 111)

Several years earlier Carl Rogers speculated that sense of self was important when he stated that a person learns significantly only those things which he or she perceives as being involved in the maintenance of, or enhancement of, the structure of self. It would seem that skill development is crucial to one's learning and that it should be integrated with, not separated from, learning of signs and symbols, e.g., the alphabet, numbers, words, etc., a fact that technological education teachers have known for years. But why is this knowledge not more widely researched/analyzed, and recognized?

Analyzing Experiential Learning

Conceptual analysis as a technique is used by philosophers to analyze illusive phenomena. By asking “what” questions and relentlessly dissecting the answers until a residue can be identified, they attempt to reveal the truth about a phenomenon. The methodology employs a test known as the necessary and sufficient conditions test. In this instance, what would be the necessary and sufficient conditions for experiential learning to exist? The following list of six conditions were developed by a class of post baccalaureate students at the Faculty of Education, The University of Western Ontario, through a group brainstorming exercise. The students were asked to identify, based on personal experience, what they considered the characteristics of learning through experience to be when they themselves felt such learning took place. Experiential learning was defined as learning which combined mental, emotional, and physiological stimuli. These necessary and sufficient conditions for experiential learning were organized and distilled from a range of individual and group responses.

1. There must be a balance of aural, visual, tactile, olfactory, and emotional stimuli.
2. Learning involves observing, doing, or living through things (it is associated with skill development, practical knowledge, and action–the result or residue of experiential learning is the long term memory associated with it).
3. Intrinsic motivation transcends extrinsic motivation.
    - The learner, in some significant respect, is the initiator of the learning.
    - The learning process, in some respect, is perceived to be controlled by the learner.
    - The goals of the learning process, to some extent, are thought to be the learner’s goals.
    - Accountability for the learning act or actions is the perceived province of the learner.
4. Analysis and reflection are a significant part of the learning act, i.e., the learner values what he/she is learning and there is an extension to that learning (the analysis and reflection gained from an experience extend it to a larger context and vice-versa).
5. The nature of the learning process itself is such that it is often associated with objectivity, subjectivity, and open-endedness [learning by experience is a trial and error process which is essentially indefinite by nature–Aristotle (cited in Kansanen, Tirri, Meri, Krokfors, Husu, &Jyrhama, 1997)].
6. There is sustainability and consistency associated with the learning (the learning act is not characterized as being associated with

immediacy—there is no deliberate recall or time-line associated with learning).

The conditions under which experiential learning were thought to exist by these teacher candidates are often contradictory to what is considered common knowledge about how children learn in school or how they should be taught. The belief that learning is a trial and error process provides one example. Children quickly learn in school that there are right and wrong answers to most questions. Most knowledge is abstracted in such a way that it can be digested in small doses, avoiding knowledge about phenomena that are difficult to define or quantify. Yet beyond a fundamental base of knowledge or literacy/numeracy, living is very much a subjective trial and error process which requires a balance of factual and practical knowledge, much of which is about ‘best’ solutions, not right versus wrong answers. Most technologists and many technological education teachers know this general truth and apply it in their own learning/teaching.

Another way of defining something from first principles is to compare and contrast it with a phenomenon that it is not. This technique is referred to by scholars as comparative analysis. Comparative researchers will often begin their studies by setting up a juxtaposition then search for a unifying concept and hypothesis to illuminate it (Thomas, 1990). For example, if learning is such an elusive concept to define, why not try to analyze what it means by comparing it to other known concepts. In this instance a comparison of what it means “to study” versus “to experience” might reveal what learning is thought to be. Could such an analysis reveal the real essence of learning? What does it mean to experience something as opposed to study it? What is the relationship of these two distinct actions and how do they impact on learning?

To study, according the Canadian Senior Dictionary (1979) is to learn or gain knowledge by means of books, observation, or experiment. To experience is to live through something, to act, to do, to respect, to suffer the consequences of, to feel, to internalize something. Could the act of studying be an aspect of experiencing? Experiencing may involve studying but it is unlikely that studying, by itself, would meet all the criteria for being called experiential learning. Yet studying has a speculative aspect to it that transcends experience in some way. The process speaks to a way of learning or thinking that is unique. It need not be utilitarian to be useful. The purposes for which study is intended determine its utility. Often this is a very personal process. The object of one’s study may have no universal appeal at all, but it is still useful to the individual who initiated it. Study, then, is often contemplative in nature. Experience, by comparison, is practical in nature.

Scholars from Finland (Kansanen, et al., 1997) recently completed a comparative analysis which helps show how study and learning are related. In their analysis they attempt to describe how teachers perceive the learning process. What happens in schools, in their opinion, can best be described as “study.” Kansanen et al., define study as what students do in response to teacher initiatives (p. 9). While they do not define the role of experience directly and how it relates to learning through study, they do refer to two different and important conceptions of knowledge, i.e., episteme versus phronesis, which are central to understanding that role. The dominating conception of rationality in educational sciences has been knowledge as episteme instead of knowledge as phronesis [cited in Kessels & Korthagen, 1996].

Kessels and Korthagen (1996) described knowledge from an epistemological view to be general by nature and usually formulated in abstract terms. Such knowledge is essentially conceptual. From the phronesis perspective a different picture emerges. Knowledge is mainly concerned with the understanding of concrete cases and complex situations. It [phronesis] considers knowledge as variable and essentially perceptual rather than conceptual.

Kansanen et al., point out that teachers' views of knowledge are central to what happens in their classrooms in terms of a practical versus academic orientation [what Kessels and Korthagen would call phronesis versus episteme and Boud would call experiential versus intellectual]. Kansanen et al., have analyzed carefully what they consider teachers' pedagogical thinking to be. One way to consider teachers' thinking, they suggest, is from the different perspectives on knowledge that they [teachers] adopt in their practice. Whether or not beginning teachers reach a level of understanding which enables them to articulate and apply concepts like episteme and phronesis to the art of teaching is, according to Kansanen et al, open to question. However, evidence suggests that teachers do have preconceptions which serve to define how they teach and what they believe about how young people learn (Zeichner & Gore, 1990). The sources of those beliefs provides part of the explanation for the dissonance some technological education teachers' feel. It may be that technological education teachers think learning to be more practical while their counterparts in other school subjects consider learning to be more contemplative, two distinct but explainable views which have implications for understanding how people learn best.

The Kessels and Korthagen reference and Kansanen et al.'s analysis are integral to understanding the role of experience in learning. Teachers' views of knowledge and the episteme versus phronesis analysis helps illuminate how experience stimulates, animates, authenticates, and reinforces learning. The practical capacity of human thought that the phronesis notion captures (where episteme does not) in conjunction with the sense of physical location argument [Harre & Gillett] provides the framework for understanding the role of experience in learning. It may also provide a rationale for practical subjects in schools, or even more important, a rationale for the use of experiential learning orientations by teachers in a wide range of subjects.

Implications

The implications of adding experience as a central ingredient to the formula for explaining learning in schools are staggering. How are teachers across all subject areas to balance these two rather distinct elements of human learning and development if they do not have an experience base themselves?

The experiences of technological education teachers may be particularly important to study if the curriculum in schools is to reflect the multi-dimensional needs of both young and mature learners and if a more complete understanding of how people learn is to be reached. Many technological education teachers have a life and work experience base from which to draw when designing learning activities in schools. More important, this base is much more central to the effectiveness of these teachers and to curriculum design generally than heretofore thought. Such teachers and the teacher educators who prepare them initially for the role of teacher would do well to ensure this aspect of professional life is valued and recognized more widely.

Is it possible that the reason so many young people have difficulty learning in school and adjusting to that discursive world is associated with how their identity is tied more to personal action and sensing than to abstract memorizing of signs and symbols? Walter and Marks (1981) suggested that, qualitatively speaking, half of an individual's reality resides in action (p. 155). The difficult time some students have with their learning in general often has to do with how they perceive themselves in relation to that learning (Purkey, 1970). Our centerings as human beings are varied and complex as Harre and Gillett's work suggests. A combination of discursive and non-discursive orientations which serves all learners may be the solution.

From a systems perspective, making experience a central element in school curriculum would mean that writing curriculum would change dramatically. Learning outcomes would likely be more difficult to articulate. Their achievement by students would be less controlled and less controllable. In the context of increasing teacher accountability, reducing teacher control on a system-wide basis could be a recipe for disorder if not chaos. On the other hand, interests outside of and inside the schooling infrastructure are calling for greater relevance in the curriculum and an experiential curriculum could be the answer.

Further Research and Reflection

While the analysis outlined in this manuscript is preliminary, it nonetheless raises some important curriculum policy questions for school leaders and for technological education teachers. In the world of technology a language, a discourse, is used that combines signs and symbols with the material and physical world; scholars often refer to it as a Newtonian Mechanics world. Working within that world requires a balance of the discursive and the manual in such a way that a sense of self is nurtured and sustained. A similar balance exists in other fields, e. g., art, medicine, and agriculture. The work of technology teachers may be particularly important to understand if learning in schools is to meet the multi-dimensional needs of young learners and if a more complete understanding of how people learn is to be reached.

To what ends does the discursive orientation in schools work? Does assimilation via academic achievement really meet our expectations as a society? Science has brought about a separation of knowledge from experience. It has also made us reliant on methods for exploring how people learn that are less than productive. Psychologists have shown that knowledge can be acquired independent of practical action, by observing and imitating others and by extracting knowledge from experiences coded in text (Buchmann & Schwille, 1983). Critics of this view argue that too much of learning, especially in schools, consists of the vicarious substitution of someone else's experience and knowledge. Recent attention in the literature on critical thinking, constructivist learning, disembodied knowledge, and situated cognition seem to favor the view that real learning begins with and hinges upon the experiences of the learner. Yet our willingness to herald this tradition in technological education is tentative.

Having explored the nature of ‘experiential learning’ and analyzed its essential features, further research, refection, and discussion are required. Which experiences are of significance? Which are not? Does sense of self lead to retention and meaning? Can experiencing something ever be celebrated so that it has the same value that study has for parents and school leaders? Can the scholarship associated with how people learn be reframed so that the educational sciences orientation, which drives curriculum development in the schools, is examined critically? A synthesis of active and passive learning will eventually emerge, but only when the premises we hold about human development in school settings are questioned and argued. Such a synthesis is an integral, albeit discrete, part of what it means to be technologically literate.

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Towards Effective Technology Education in New Zealand

Maxwell S. Reid

Introduction

New Zealand is a small former British colony in the South Pacific with a population of 3.9 million people. The small economy of the country is heavily dependent on overseas trade. Historically, a large proportion of New Zealand's exports, mainly agricultural products, went to the United Kingdom. In the past 20 years, however, New Zealand has had to adapt to a changing world, so that now our largest exports are to Australia, Japan, the United States, and China. New Zealand has, of necessity, moved away from its dependence on dairy, meat and wool exports, as the new industries of forestry, horticulture, fishing, manufacturing and tourism have become more significant (Department of Statistics, 1999). These changes, together with the huge advances in the associated technology, have created dramatic changes to our economy, and consequently, the fabric of New Zealand society.

There has been an increasing awareness of the delicate balance of our ecology, culture, economy and growth of a new independence. Major cultural changes, such as those that have resulted from our anti-nuclear stance, together with the re-emergence of a sense of identity within the indigenous Maori people, has resulted in the adoption of the Maori language an official language of the country. Along with this a unique New Zealand identity and culture has developed. The result is that New Zealand has of necessity grown away from the traditional colonial influence of England.

These words in the Anglican Book of Common Prayer (1928) are still true: "we are living in a new world…new knowledge and new ways of life bring with them new customs and forms of speech unknown before" (preface). Such changes have never been more explicit than in the field of technology, which has changed our ways, customs, and speech as no other aspect of daily life in New Zealand has.

This paper examines the historical concept of technical education in New Zealand as it developed from the British model. It examines how England and Wales designed and introduced a new technology curriculum, and how, of necessity, a New Zealand technology curriculum has been developed which is more suited to New Zealand's developing culture. The paper focuses on the

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process of curriculum development. It illustrates some of the good features and some of the difficulties resulting from the introduction of technology as a subject in New Zealand schools in 1999. As an evaluation of technology education in New Zealand, this paper is preliminary, and an interim account of a change process that will continue well into the early part of the new century.

The New Zealand Education System

The educational system of New Zealand, a former British colony, has understandably been influenced by the British school system. The public primary schooling system introduced in 1877 was made freely available to as many children as possible, and was "modeled on British and Australian counterparts" (McKenzie, 1992, p. 31). Until quite recently the New Zealand school system has been based on the three-term year, which was deliberately arranged around the New Zealand agricultural calendar, the breaks coinciding with:

- haymaking in January
- harvest/picking season in May
- lambing/calving in August

The late 19th century introduction of secondary schools to New Zealand was unashamedly academic. The secondary schools aligned themselves with the University of New Zealand by adopting the Matriculation Examination as an entrance requirement to University (Campbell, 1941). According to Lee, (1992) "English thinking dominated schooling policy and practice in the young colony…secondary schools were inaccessible to most youth, particularly working class children" (p. 103). In 1901 a *free place* system was introduced in which every child was to be offered a free place in a secondary school. The tendency that followed was for most pupils to remain at secondary school for a short period only, while following an academic course (Lee, 1992; McKenzie, 1992).

Curriculum reform was clearly desirable. The Minister of Lands in 1900 (cited in McKenzie, 1992) stated, "it was obviously the case in that children in the rural areas should be studying technical or agriculture subjects that would have a distinct bearing on the occupations in those localities" (p. 31).

As a result, by 1910 technical high schools had been established in the major centers throughout the country. This secondary school system now simulated the British tradition where middle class and academically strong went to a public or grammar school, and the working class went to a technical high school (McKenzie, 1992). (Although New Zealand society claims to be relatively classless by the British standards of family class structure, the division in any appearance of a New Zealand class structure is measured by an individual's wealth, rather than one's family connection). As a typical example of this division in the early secondary education, the city of Hamilton is a small inland New Zealand city at the center of one of the richest agricultural and pastoral areas in the world (Campbell & Campbell, 1999). Hamilton had two secondary schools until the late 1950's, and prospective students were required take an entrance exam as a requirement to gain entry to Hamilton High School (HHS). The remaining students went to the Hamilton Technical College (HTC) for a technical (or pre-vocational) education. The Hamilton historian Gibbons (1977) described HTC as offering practical instruction for quite specific skills and careers, “to teach practical knowledge to the artisans and labourers of the future” (p. 164).

In the cities, New Zealand’s technical high schools typically offered boys pre-vocational streams of engineering, building, or an agricultural course to give them a practical skill preparing them for the non-professional workforce (Lee, 1992). Academically less able female students were offered a commerce stream with subjects like typing and bookkeeping to prepare them for commerce, where it was expected that they would work, or alternatively as Gibbons (1977) described, “needlework, cooking and domestic economy” (p. 164). The small populations of the rural districts could not sustain a two-school system, and these post-primary schools, of necessity, continued to be mixed or comprehensive. Such a system in these schools was now similar to the early British secondary school system on which ours was modeled (McKenzie, 1992). As described by Black (1994) “the major subject had hitherto been academic, with the vocational studies reserved for older students classed as less academically able” (p. 2). De Vries (1992) described a similar system in the Netherlands in which the courses were categorized as either “pre-vocational or pre-university” (p. 28).

The technical high school system, (or the technical streams in the comprehensive school), offered the students an education that they would otherwise perhaps not get. Gibbons (1977) pointed out that “in many ways Hamilton residents were much more enthusiastic about the technical school than the ordinary high school…most adult Hamiltonians up to the 1920’s had received little or no secondary education” (p. 164).

The Technical high school system had the following drawbacks:

(a) Although a technical education was commonly thought to give the students who left school at the age of fifteen a useful start in industry, commerce, farming, or homemaking, it became increasingly so at the expense of a more rounded general and intellectual education. Within the British origin of a class system, this was never a concern in the British education system on which it was modeled (Black, 1994).

(b) Pre-vocational courses were generally perceived (by parents and students) as for less able students, giving the subjects a low status, even if this was never the intention of a particular school offering the subjects (de Vries, 1992). McKenzie (1992) observed “Inherited attitudes of the United Kingdom were an added handicap. In Britain, separate technical schools were typically associated in the public mind with second class knowledge which provided the limited skills and disciplined work habits of a docile working class” (p. 32). Similarly, the common fear of ambitious youth in New Zealand was that if they were directed into technical curricula, their vocational opportunities would be restricted (McKenzie, 1992).

(c) The system was sexist. The provision of a vocationally oriented education in reality, as O’Neil (1992) subtly put it, “meant the

> formalised entrenchment of gender differentiated (practical) vocational courses…male pupils took vocational courses for their future paid employment, some females took them for theirs, but many did so in the light of their expected future in unpaid domestic labour" (p. 88).

By the 1930s, there was a strong case to dispense with the two types of school, and thereby dispense with the associated class attitudes. In 1945 the Department of Education imposed a common core curriculum on all types of schools. This did not inhibit the ambitions of the academics or frustrate the aspirations of the ambitious, but it ensured a common range of studies, including craft subjects for the junior pupils (McKenzie, 1992). Students at post primary schools were able to take technical subjects, including workshop craft subjects (Ministry of Education, 1995). While this education system and its crafts may have been appropriate for earlier times, in more recent years it has generated the following problems:

- Frequently, the technology learned in schools did not help students in society because the equipment they used was often industrial or commercial cast-off and therefore likely to be obsolete and out-of-date. Johnson (1992) stated that "tremendous changes have occurred and will continue to occur in the workplace. Equipment and processes are becoming more sophisticated. This sophistication has resulted in fundamental changes to the skills needed by workers" (p. 1). As Black (1994) pointed out, "pupils are to be taught woodwork, metalwork and perhaps also about forming plastics. This prepares them for industries of the 19th and early 20th centuries" (p. 114). Unfortunately, if you were not academic, the skills being taught were no longer appropriate. Jones (1996) commented on early attempts at the inclusion of technology in the school programs: "technology as it has developed in past curricula encompassed a limited range of skills, processes and knowledge resulting from a narrow perspective" (p. 6).
- The school environment can be unrealistic and lack an examination of the social issues of technology. Zuga (1992) concluded in her research that, "…at best, schools are insulated from society and serve to preserve the status quo and schools are subject to the whims of fads and special interest groups" (p. 52).
- Medway (1992) commented, "There is nothing wrong with craft skills themselves as an element in education. The problem with traditional craft teaching—woodwork, for example—as an educational endeavour has rather been that the disciplines are learned within a context that limits their general applicability…to build a coffee table in school is to learn not a generalised competence capable of application anywhere but a competence for one context, school" (p. 20).
- The teaching of technical subjects requires skilled teaching staff. The separate technical and craft learning activities in New Zealand tended to be isolated from each other. The technological knowledge areas were not linked in a structured manner in which the knowledge could transfer from one situation to another. Raizen, Sellwood, Todd, & Vickers (1995) indicated the desirability of a socially structured link between the

theory and the practical aspects of technology. Such programs can help students "begin to think differently about their school subjects as they put knowledge from several fields to work in an attempt to solve practical problems" (p. 53).

- The curriculum did not encourage team working. In today's work environment it is likely that a professional will have to work in a group relationship to solve a problem or operate a system. "No longer can any one person be expected to master a body of knowledge" (Braukmann & Pedras, 1990, p. 3). Resnick (1991) offered the view that "groups are especially preferred when several kinds of knowledge and expertise are required, that call for the participation of several individuals whose work must be coordinated" (p. 14).
- The curriculum was not considered responsive to New Zealand's particular needs, languages, and cultural differences. In particular said Jones (1996), "…not maximising learning for Maori, Pacific Island students and for girls" (p. 2).

Although New Zealand has this long history of technical education in the intermediate and secondary schools, the delivery of general secondary school education has not always related the students to a realistic social framework of knowledge which is applicable to an increasingly technological world. What is required is a technical education system for all students (Burns, 1992). However, unlike the traditional technology programs, which formerly taught only skill-based programs, the technology instruction in schools must change to meet the needs of a technologically advanced society. Johnson (1992) asked the question, "given the fact that the skills needed by the workforce are changing and the increased need for all citizens to have high level thinking skills, are the students being provided the opportunity to acquire those skills?" (p. 27).

New Zealand underwent major curriculum reforms in the 1990's. The development of a national curriculum was part of this reform (Jones, 1996). This resulted from growing concerns with school curriculum (Jones, 1996). During the 1970s and 1980s, calls were made for a curriculum that was responsive to New Zealand's needs for people highly skilled in science and technology, and with the language and cultural sensitivity needed to maintain international economic competitiveness (Levette & Lankspear, 1990). Technology subjects need to be accessible to all children, regardless of gender or social standing. Along this line, Black and Harrison (1985) proffered the general idea of technological capability with a *task-action-capability* (TAC) approach. They listed three interacting personal attributes required in the education of children to be of direct practical value in the real world:

- "*Resources* of knowledge, skill and experience which can be drawn upon, consciously or subconsciously, when involved in active tasks.
- *Capability* to perform, to originate, to get things done, to stand by decisions.
- *Awareness*, perception and understanding needed for making balanced and effective value judgements" (p. 54).

Technology Education in England and Wales

In 1990, the New Zealand Government, influenced by the changes taking place in England and Wales, embarked on a project to revise the school curriculum (Jones, 1996). In 1991 the New Zealand Minister of Education requested the development of a technology curriculum as part of a broad initiative at improving student achievement. The initial development phase included a scrutiny of technology education developments occurring in other countries (Ministry of Education, 1995). The introduction of a technology subject in schools was a worldwide trend this decade (Black, 1994; Mather, 1996).

Understandably, there were problems in the introduction of the technology curriculum in England and Wales. A study of that curriculum implementation process would no doubt be beneficial to curriculum designers who followed. Since the introduction of the technology curriculum in England and Wales had an influence on the revision of the New Zealand curriculum (Jones, 1996), the lessons learned there naturally become part of the development path of the New Zealand curriculum. It is therefore appropriate to review them.

Technical/vocational education in English and Welsh schools by tradition had been centered on the crafts, and art and design. The craft education was really of two strands, trade craft, stemming from nineteenth century type manual training, and the village type craft. While both of these areas were responsible for teaching children manual skills, it became increasingly difficult later to represent modern industrial practice in schools. Craft work has serious limitations as a foundation for modern technological activity. It may give experience in designing and making, but it falls short of modern industrial activity, intellectual concepts, modern cultures, and realistic working environments (McCormick, 1992a, 1992b). As Medway (1992) observed, the craft areas of the curriculum actually had been moving substantially in the direction of intellectual stimulation for some years. “The craft processes of woodwork and metalworking had been supplemented and partially replaced first by design and then by elements of physics and engineering” (p. 4). The 1989 research of Layton, Medway & Yeomans (Cited in Medway, 1992), showed that two results were clearly apparent:

1. Technology had risen in status and was attracting more able students,
2. Children who had previously found enjoyment, success, and self-respect in the craft subjects, no longer found them in the written scientific demands of the reconstructed technology subject.

By the 1980’s, it was recognized in Britain that there was a clear need to raise the status, prominence, and effectiveness of technical education. McCulloch, Jenkins, and Layton (1985) talked of the need to raise its status to a prominence that it enjoyed in other countries such as West Germany. Similarly, Weiner’s 1981 examination of English culture, (cited in Black, 1994), expressed concern about the British lack of industrial competitiveness and enterprise. He referred to the depressing effect of the gentlemanly English culture, which despises industry and disdains practical activity (p. 33).

In 1988 the British Education Act published the decision to include technology as a compulsory national curriculum subject to be studied throughout

England and Wales. This new subject of technology was seen as meeting the needs for a discipline which would be “both intellectually stimulating and legitimate in the eyes of career-minded students and their parents” (Medway, 1992, p. 4). However, there were many problems defining the nature and scope of technology education, as a detailed specification of the National Curriculum was not complete (Harrison, 1992; Barnett, 1994) and both teachers and pupils were evidently confused about what counted as technology (Harrison, 1992; Barnett, 1994; Jones, 1996). As Taba had pointed out in 1962, the confusion surrounding curriculum development often stems from insufficient “analysis of what knowledge in any subject or discipline consists of” (p. 172).

Consequently, the *National Curriculum Order for Technology 1990* was issued to settle this confusion (Barnett, 1994). It was hoped that some of the conflicting issues, statements, and other confusion would be accommodated in this paper. This national effort brought the subject of technology into the curriculum, but not as a unified subject. It was identified as a *foundation subject* which could be construed as not as important as a *core subject* such as science (McCormick, 1992b).

The National Curriculum specified two distinct profile components, *design and technology* and *information technology*. McCormick (1992b) analyzed the curriculum and concluded that, “for all intents and purposes these are two separate elements, with information technology being cross-curricular” (p. 18). It appeared that all the previous craft subjects were to be coordinated into integrated design and technology activities. The main problems were:

1. Very little content was specified directly (Harrison, 1992; McCormick, 1992b). The guidelines were vague and open to interpretation. Assessment was even more difficult. McCormick further commented on the vague and abstract nature of the program (1992a), “… besides the level of complexity, one of the major problems was the difficulty in interpreting what some of the statements meant. They had been deliberately kept at a level of generality to try and avoid prescription” (p. 48).
2. The curriculum did not have a coherent knowledge base of its own. The initial 1990 design was a mix of the existing technology, art, and craft subjects, which were scattered among the various attainment targets, involving different levels of compromise for existing teachers (Paechter, 1992; Harrison, 1992; McCormick, 1992b).
3. There were five unrelated knowledge perspectives designed. Black (1994) observed that “each competing perspective differs from the others in its particular priority and aims, and also in justifying a particular group of teachers, and often threatening other groups” (p. 115).
4. Although the subject rose in status to recruit more able students, students who had previously found enjoyment, success, and self-respect in the crafts (and often nowhere else) ceased to find them in the written and scientific demands of the reconstructed and renamed subject technology (Medway, 1992; Harrison, 1992).

5. The requirement of the technology curriculum that, “Admissible activities must involve developing an explicit design proposal” was unusual because in a large proportion of industrial situations, those who develop and design don’t usually build, and those who build, don’t usually design (Medway, 1992, p. 16)! McCormick (1992a) commented, “Design, important though it is, is undertaken by only a fraction of those working in technology” (p. 47).
6. The subject was difficult to implement. McCormick (1992a) wrote, “…from a point of view of implementation, there was the idea that design and technology would be taught by existing teachers from subject areas of art and design, business studies, craft design and technology, home economics, and information technology. This implied the bringing together of teachers who had no real contact in the past and putting them under pressure to co-operate” (p. 48). There was debate and contestation between teachers of the various subcultures within the overall group (Paechter, 1992).

Medway (1992) expressed some of these frustrations in his analysis: “It is interesting and important, therefore, to ask how this new subject got itself invented and included, and what the implications are of the shape which has been given to it”. He claimed the process to be, “…on one hand educational idealism and well-founded theory and on the other, conceptual confusion, unrealistic aspirations and ideological loading, and to an outcome which is bizarrely radical and conservative by turns” (p. 1).

As a consequence of these early difficulties in the implementation, a major curriculum review began in May 1998 involving teachers and other interested groups to develop improvements to the entire school curriculum (Qualifications & Curriculum Authority, 1999). The review was published in May 1999. The entire revised national curriculum is available (Department for Education and Employment, 1999).

It is always easy to criticize, but these early efforts in the UK had made positive steps towards solving an international educational problem. Influenced by this early international research, New Zealand educators took a fresh approach to the development of New Zealand’s technology curriculum.

The New Zealand Technology Curriculum

Following a decade of educational review (Department of Education, 1987), the Government of New Zealand undertook a revision of curriculum in 1990 under the banner of *The Achievement Initiative* (Ministry of Education, 1991). The object was to explore ideas influenced by the curriculum reforms that were taking place in England and Wales. A Ministerial Task Group Reviewing Science and Technology Education was set up in 1991 which made many recommendations, the most significant being that a technology curriculum be developed as an area in its own right. The report recommended a technological education for all students, to develop people who are creative, innovative, and resourceful—and who can combine enterprise, initiative, and imagination with knowledge and skills. The report went even further in its recommendations to include:

- the importance of teaching and assessing interpersonal, communication and broadly-based practical skills;
- a broad range of knowledge and skills recognized by assessment procedures;
- adequate teacher training and resourcing for technology education;
- Maori input and inclusion of the use of Maori language. (Ministry of Research, Science and Technology, 1992).

The University of Waikato was contracted to write a draft curriculum for New Zealand schools (Jones, 1996). Consequently, the current *Technology in the New Zealand Curriculum* was printed in 1995, and has subsequently been issued to schools (Jones, 1996). The achievement objectives of the curriculum are:

Strand A: Technological Knowledge and Understanding

Within a range of technological areas and contexts, students should develop and understanding of:

1. The use and operation of technologies;
2. Technological principles and systems;
3. The nature of technological practice;
4. Strategies for the communication, promotion, and evaluation of technological ideas and outcomes.

Strand B: Technological Capability

Within a range of technological areas and contexts, students should produce technological solutions. They will:

5. Identify needs and opportunities to provide information for possible technological practice;
6. With reference to identified needs and opportunities,
   (a) generate possible options and strategies, and select, develop and adapt appropriate solutions;
   (b) produce technological outcomes to agreed quality standards, managing time, using human and physical resources skillfully, safely and effectively;
   (c) present and promote ideas, strategies, and outcomes throughout technological practice;
   (d) evaluate designs, strategies, and outcomes throughout technological practice in relation to their own activities and those of others.

Strand C: Technology and Society

Within a range of technological areas and contexts, students should:

7. Develop awareness and understanding of the beliefs, values, and ethics of individuals and groups:
   (a) promote or constrain technological development;
   (b) influence attitudes towards technological development;
8. Develop awareness and understanding of the impacts of technology on society and the environment:

(a) in the past, present and possible future;
(b) in local, national and international settings.

The curriculum is a multi-layered structure. Each of these three strands has 8 levels of itemized achievement objectives, to serve the subject as the children progress through the school system over a period of 13 years (Technology in the New Zealand Curriculum, 1995).

The New Zealand technology curriculum is the result of a group of experienced curriculum writers, some of whom had had experience in re-writing the science and mathematics curriculums. The development policy was a result of the wider community input (Jones & Carr, 1993) and also a result of much international research into technical education, teaching, and learning (Jones, 1996). It should be noted that the New Zealand curriculum is not simply the copy of an overseas model with a few wording changes. It is a break from the British modeling of the past, with a new subject that is reflective of New Zealand conditions and culture, and with a knowledge base of its own which incorporates a balance of intellectual, social, and personal interactions with technology. The curriculum appears to be well balanced. It is not a fragmented assemblage that tries to cobble together a whole spectrum of existing subjects and crafts. The design may be varied to suit particular areas of the country and it is also versatile enough to reflect current technological practices.

Problems Facing New Zealand Technology Teachers

It may be difficult for the technology curriculum to succeed until it has full status, equal to other subjects in the school curriculum (Jones, 1996). In the transition stage there are potential problems in the successful introduction:

(a) As McCormick (1992a) had observed with the prototype England and Wales technology curriculum, many of the original technical/craft subcultures do not naturally work together. The former areas of arts and crafts that were rather specialized are now merged into a new curriculum where technology teachers are no longer required to be expert in a very narrow field of technology. Most of the non-technical teachers will initially lack the appropriate technological expertise. Similarly, the former specialized subject teachers will now require more general knowledge and skills in technology and education. The recommendation of the Ministry of Research, Science, and Technology to provide for adequate training and resourcing must be taken very seriously.

(b) It follows from the above that the teachers will not always have the answers and must of necessity change their roles to mentors and facilitators. While the successful teaching of the subject will encourage talking, the exchange of ideas, questioning, and curiosity which is excellent for the development of group dynamics, some children's cultures do not encourage it. Moli (cited in Hodson, 1999) observed of the Polynesian immigrants into New Zealand that "…many have learned from parents that the teacher, like the priest or pastor, holds valuable knowledge and as such is to be respected, not questioned by mere students. Indeed, to ask a question can be a sign of lack of attention and disrespect. …to teach the children to be critical thinkers and to ask questions in an inquiry approach is certainly opposing the conforming aspects of the culture" (p. 216). It is not a problem just for one culture in our multicultural New Zealand schools and society. Hodson (1999) observed that "…girls brought up within the Islamic tradition may experience difficulty in challenging what they perceive as the proper authority of an adult male teacher" (p. 228).

(c) The standard New Zealand primary classrooms do not have facilities to out carry some of the curriculum projects.
(d) The development and implementation of the subject can easily be undermined by misinterpretation (Jones, 1996).

To solve these problems, and successfully implement the technology curriculum, the teaching of technology as we have known it in the past will change. Vincent and Vincent (1985) stated that "curriculum change may denote bringing about changes in methods of teaching and learning, as well as changes in the programmes or courses" (p. 27). The curriculum states that a timetable for the subject of technology "allows for teachers to work collaboratively in planning and delivery" (Technology in the New Zealand Curriculum, p. 29). Effective planning of the subject necessitates an increase in the number of meetings the teachers must attend which, in turn, has increased their workload (J. Moreland, personal communication, July 31, 1999). Recognition of this problem has resulted in a reduced requirement for teaching technology in the first year of the programme's implementation. A gradual phasing in of the subject resulted in a partial implementation of years 7-8 and 9-10 in 1999 (New Zealand Education Gazette, 1999).

Conclusion

Technological knowledge is increasing at an exponential rate and the professionals of today work in environments where they can no longer be expected to learn in advance all the technological knowledge required to solve day-to-day problems. Knowledge must constantly be acquired in order to understand technology and solve the problems of the time. It is difficult to train a person for a professional situation where the demands of tasks may be to some extent unpredictable, and where the knowledge and skills needed are not usually defined by some prior instruction or coaching of the concept or process. McCormick (1997) stated: "Technological activity is by nature multi-dimensional, requiring understanding from a variety of points of view" (p. 144). In addition, most people working in a technological occupation must retrain in technology at least once in their working lifetime.

As this knowledge explosion continues, the balance between *what to learn* and *how to learn* must shift towards the latter. Given the impossibility of knowing everything about anything, the educational requirements for a job and those for higher education are converging. The Carnegie Task Force (cited in Malcolm, 1988) observed that "…the economic and social needs of our country will force us to provide for many the kind of education previously reserved for the elite few" (p. 224). Vincent and Vincent (1985) go even further and stated that “Oral and social skills, it is argued, are the skills most employers need from their employees” (p. 108).

New Zealand education has taken positive steps to define and establish technology education as an academic discipline to replace traditional school craft subjects. All students are expected to study technology following a structured progression of the curriculum from their first year in primary school to their senior secondary year 13. The success of the technology curriculum will depend upon its successful implementation in the schools, together with the development of an effective assessment program. Naturally it will take time to develop a culture of technology education in New Zealand schools, as “…technology education does not have a historical home in New Zealand” (Jones, 1996, p. 24). The exams that students sit in the 7th form (the final secondary school year required as a university entrance qualification) are the exams that possess social status. It can be expected that the subject of technology will gain an appropriate social status and break its current shackles as a pre-vocational course when it eventually becomes a 7th Form exam. The examination unit standards for the subject are currently being written and will be phased in gradually, starting in 2001. A panel of academic professionals is developing the achievement standards, professional development requirements, and resources for year eleven and will be introduced in 2000 (P. Petherbridge, Ministry of Education, personal communication, 19th November 1999).
Unlike the old pre-vocation training in the technical schools, the new subject of technology will be of assistance in acquainting the New Zealand pupils with the aspects of technology that are important in the 21st century. It will provide students with the knowledge and skills that will be useful, regardless of the career path they choose, by increasing their options, horizons, and perspectives).

The process that resulted in *Technology in the New Zealand Curriculum* was designed to give the students an understanding of the culture, the values, and the social issues involved with technology. It is intended to bring the concept of technological literacy into the intellectual domain. Such an understanding and intellectual approach to technology is now deemed necessary for all students in order for them to function effectively in our modern technological society. The new subject will lay a good foundation for further technological learning in school as well as the inevitable learning that takes place outside the school in the home and at work.

Nickerson (1988) went even further in expressing the view that technology education will “…increase one’s appreciation of other cultures, viewpoints and lifestyles, and deepen one’s sensitivities to other people’s rights, feelings, preferences and hopes…it should heighten one’s curiosity and inquisitiveness; as a consequence of one’s education, the world should be a far more interesting place than it would otherwise be” (p. 4).

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Design: The Only Methodology of Technology?

P. John Williams

The Nature of Technology

Technology, and certainly technology education, can be characterized as more of an activity than a discrete body of content (McCormick, 1996). Technological knowledge can be divided into procedural knowledge which relates to the activity, and conceptual knowledge which relates to the body of content (Hennessey & McCormick, 1994). There is probably more international agreement among technology educators about the activity of technology than about the content of technology. This is a helpful separation to make when designing curriculum and discussing teaching, but it is not a separation which should be evident to the students. Students should perceive technology as a thoroughly integrated activity, not one which can be separated into content and process, or theory and practice. Some curriculum documents separate these two areas of knowledge. An example is the two attainment targets in the UK technology curriculum of Design and Make. In others, the differentiation is less such as the Content Standards of the Technology for all Americans Project (ITEA, 1998).

While the traditional focus of technology education has been on activity, i.e., on doing and making things, this has represented a narrow interpretation of procedural knowledge. This focus has not been accompanied by an emphasis on all aspects of procedural knowledge, but has typically been concerned with those procedures most closely aligned with the development of manipulative skills and how to use tools effectively and safely, for example.

A relatively recent realization has been that there are many significant cognitive skills which are important for students to develop, and which are suitable to be developed in the unique context of technology education. The term unique is appropriate because there is no other curriculum area in which students have as significant an opportunity to think and reflect and develop ideas, and then to test their ideas in a practical context. The development of these cognitive skills occurs through the procedural knowledge of technology education.

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Procedural Knowledge

Procedural knowledge is developed through the creation of a process, as when a solution to a particular need or brief is sought. There are a range of these processes which are utilized in the development of technology and therefore may also be appropriate in teaching technology, the two most common being design and problem solving.

The place of procedural knowledge in the US Standards for Technology Education is developed as “Design,” proposed as one of the five major organizers of technology education. This equation of the technological process with design is further reinforced by another of the organizers, namely “The Designed World.”

A common approach in teaching the technology process is to map out a series of steps for students to follow as they make projects. Examples include design-make-appraise (Australian Education Commission, 1994), identify-design-make-evaluate (UK Department of Education, 1995), and define problem-ideas-model-test (USA International Technology Education Association, 1998). The idea is that this systematic process can be taught and learned by all pupils who can then apply it to subsequent problems or situations. These are often reproduced in booklet form as workbooks for students to use as they design. However, research has revealed that it does not work this way, either in reality or in the classroom. Neither students nor designers naturally utilize a predetermined process in their work; they invent a process as they proceed toward task completion. This is well illustrated by Petroski (1996) in his book *Invention by Design* where he details the design and development of things like paper clips, pencil points, and zippers.

The parallels with science education are interesting. As with technology, and even more specifically with design in technology, studies of scientists at work seem to indicate that there is no generalizable method (Carey, 1994; Gibbs & Lawson, 1992; Chalmers, 1990; Gjertsen 1989). The notion that there is a common series of steps followed by all research scientists, such as defining the problem, gathering information, forming a hypothesis, making observations, testing hypotheses, and drawing conclusions, is not generally held.

One of the reasons for the continued perpetration of this myth is the way in which results are presented in research journals (Medawar, 1990; McComas, 1996). The standardized style of presentation makes it appear that all scientists follow a standard research plan. Scientists approach and solve problems in many different ways, using the skills and methods used by all problem solvers in whatever area.

The Processes of Science and Technology Education

Both the content and the processes of school science have traditionally been drawn from the pure science category of scientific activity. This means that the content was studied in strictly disciplinary categories, and the process was a prescriptive and linear one of defining the problem, gathering information, forming a hypothesis, making observations, testing hypotheses, and drawing conclusions. This method serves to work against the creativity element in science. For example many laboratory exercises are simply verification activities where teacher discussion is followed by step-by-step instructions and work toward a predetermined solution. This is the antithesis of the way science really operates, and is no longer generally accepted as appropriate (Woolnough, 1994).

An advantage of science over technology in the educational context is the definition of the body of knowledge within which the processes can be pursued. Despite the fact that many science educators are calling for a reorganization of this content into something which is more relevant and meaningful for students, the traditional organization is accepted and in place. Fensham (1985, p. 417) makes a similar point with regard to science, that despite the rapid growth of scientific knowledge, the specific conceptual content in science education consolidated rather than diversified, the rationale being that the “powerful” organizers were those which scientists everywhere used repeatedly. In technology there is no comparative consensus on the conceptual organizers of the content, although attempts have been made to this end in the USA (Hales & Snyder, 1982; ITEA, 1998).

An analysis of the way scientists work, and the development from that of skills which may be appropriate in the teaching of science, has been done in many curriculum projects (Woolnough, 1994). In commenting on this reductionist approach, Woolnough concluded that it is not very helpful because doing science is more that being competent in a series of scientific skills. “The whole activity of doing science does not equal the sum of the parts, it differs from and exceeds it” (p. 18). This method of deriving processes from the real world, however, is not necessarily reductionist, and could remain a valid insight for students into the world of doing science.

In technology, what Woolnough refers to as the reductionist approach is a recognized source of ideas about processes. The methods used in the advance and development of technology are recognized as appropriate methods and processes for technology education. But at the same time there is recognition that technology is also more than the accomplishment of a set of process steps. The outcome of a design, or the solution to a problem, involves more variables than can be represented in a sequence of process steps.

This reductionist approach to processes in science or technology serves to identify many of the individual and specific activities in which practitioners engage as general life skills, such as planning, observing, reporting, evaluating, and communicating. These activities only become science or technology when they are contextualized, when they are accompanied by scientific or technological knowledge, and set in the context of a scientific investigation or a technological design.

Constructivism

The current incorporation in science education of constructivist notions of learning are not derived from the conduct of real science, but rather from research about the way students learn. Constructivism holds that students learn by constructing knowledge in certain ways, and the teaching of science will be facilitated if the presentation of content is organized in these constructive ways. Real science is not really done constructively, nor is scientific knowledge developed constructively. The goal of scientists is often not necessarily to simply add to the domain of scientific knowledge (even in pure science this may be a spin off rather than the primary goal) but to understand, for example, how a specific object functions or behaves. There is a difference between scientists' cognition and students' cognition; children construct knowledge in different ways.

Is constructivism then also an appropriate approach to technology education? I don't think so, because the development of knowledge is not the primary goal in technology. Knowledge is only developed to the extent that it assists in the completion of a task; the criterion becomes: *Is it useful?* Not, as in science, where the criterion is: *Is this knowledge appropriate in the development of students' perceptions of the theory of the reality around them to explain their sense impressions?*

So while in science education the presentation of new knowledge to students must be carefully selected and managed to allow its construction in relationship to what is already known, the rationale for the introduction of new knowledge in technology is its usefulness in progressing toward the completion of a task.

General Versus Vocational Approaches

Questions related to the importance of the process must also relate to the vocational or general philosophy of the subject. Where the goal is vocational, in science to prepare scientists and related professionals, and in technology to prepare technologists at all levels from engineers to tradesmen, then the assumption is reasonable that the methodologies employed in teaching, and the consequent processes employed by the students in learning, should be derived from the practice of the discipline. If however the goal is general, to develop a more scientifically or technologically literate citizenry, then what is the rationale for deriving the educational processes from the discipline? Surely it would be more reasonable to derive them from learning theory, and to some extent this is happening in science education.

For technology education, however, this logic does not apply because the procedural knowledge enhances the level of general technological literacy in the area. For example, if in technology a design process was being utilized as both the pedagogy of the moment and the process that students follow in a particular task, then conforming to a constructivist framework for the development of knowledge would be inappropriate. This is due to the fact that a structured sequence in the development of knowledge/understanding is irrelevant given that the defining criteria for relevant knowledge is not what fits together developmentally, but that which works toward the satisfaction of the design brief.

The compatibility of vocational and general approaches to either science or technology has been rejected (Fensham, 1985, p. 417; Williams, 1998) despite, or in spite of, continued curriculum development efforts to amalgamate the two. The approaches are incompatible in terms of methodology (teacher centered vs.

student centered), assessment (competency vs. outcomes), and pedagogy (didactic vs. inquiry).

Technology Processes

There is a range of activities in which students are engaged when they “do” technology. They do not necessarily do all the activities every time they complete a task, and certainly do not do them in the same order every time. The activities depend on the nature of the student and the nature of the problem. There are many activities in this process, but the most important include:

- evaluation,
- communication,
- modeling,
- generating ideas,
- research and investigation,
- producing
- documenting.

It may be appropriate that these activities be called *aspects* rather than *stages* of the process; *stages* has a sequential connotation which is not appropriate as a technology process.

If these aspects are standardized and sequenced for all students for all projects, then it is not possible to achieve the goal of revealing the cognitive development of students through the documentation of their design process. This is the case because they are being forced into a way of thinking that has been predetermined by the teacher. Their cognitive development is neither revealed nor encouraged. These activities are not ends in themselves, but rather are done and practiced in order to achieve other goals. These other goals include students becoming independent problem solvers, becoming creative and reflective, and becoming critical and expressive; that is, the goals are achievement of the generic competencies that all students need and should have upon leaving school (Mayer, 1992).

The situation in Western Australia is representative of more global thinking about the nature of the processes of technology. There has been a move away from the notion of a prescribed process such as Design-Make-Appraise (Australian Education Council, 1994) to the idea that there is a range of processes in which students are engaged when they do technology (Curriculum Council, 1997). These processes of technology may include those enumerated in the following section.

1. Design

Design is justifiably the most common and popular of the processes appropriate to technology education, and has been identified as such in the US Standards for Technology Education (ITEA, 1998). In the real world it is a significant process in the development of technology in many disciplines from engineering to architecture, and from an educational perspective it is an ideal methodology to use as a vehicle to achieve the desired competencies.

There is very little research about design, and therefore very little informed guidance on how to teach it. But there is some. There seems to be no simple generalizable process. “The processes involved in designing are not linear, they do not always start from human needs, and they do not always proceed in an orderly way. They are reiterative, spiraling back on themselves, proceeding by incremental change and occasional flashes of insight” (Baynes, 1992).

Research has been conducted on both expert designers and children doing design in a technology education context with some parallels in the findings. What students do when they design in technology is a very convoluted and complex process, and is different every time they design something. Studies of designers working in technological fields also reject the notion that what they do can be represented by an algorithm (Hennessey & McCormick, 1994). So both seem to adopt inventive and flexible approaches which are adapted to the situation in which they are working. Individuals also seem to have preferences for how they design.

In the design situation where teachers insist on progressing through set stages, students in fact adopt their own strategies in order to get the job done, but ritualistically use the teacher’s approach to satisfy assessment demands (Hennessey & McCormick, 1994). For example in the common requirement to sketch four design alternatives to a problem or brief, a student is often interested in only one, and does the others just to satisfy the teacher. In this case the goal of generating creative ideas is not being achieved and students do not reflect on the process, for example, by asking what, why, what order? This requirement therefore has no impact on student thinking or the development of creativity.

2. Problem Solving

The appeal of problem solving as a methodology lies in the fact that it is a natural activity; humans have always been faced with problems and tried to solve them. In this sense it is also a useful model for understanding technological development in that it can incorporate the broad range of variables involved in the solution to a technological problem.

Despite the fact that the terms *design* and *problem solving* are often used interchangeably, problem solving is different from design in that design deals with ill defined problems and may not begin with a problem, while of course problem solving does.

It is helpful to clarify different types of problem solving. McCormick (1996) identified three types of problem solving:

- a general problem solving approach referring to the process more than the problem itself.
- a global problem referring to a significant problem, the solution to which will take some time.
- emergent problems which arise throughout any process and must be overcome in order to proceed.

3. Systems Approach

A systems approach (input-process-output) is often placed in a problem solving context. For example, in many technology curricula in the USA a system is represented as a solution to a problem. A systems approach may be either analytical, and thereby used as a way of viewing the world or a specific context or object, or functional in that a systems process is followed for diagnostic or production purposes.

Many generic groups of systems are represented in the literature. Examples include structural, mechanical, electronic, communication, production, transportation and biotechnological systems. These systems represent much of technology, and are often used to reduce a technology to a simple graphic model that illustrates basic elements. This representation can extend to quite complex elements such as systems maps, influence diagrams, and flow-block diagrams (McCormick, Newey, & Sparkes, 1992, p. 146)

4. Invention

Inventions may be accidental or intentional. Authors such as Ferre (1995) equate the accidental with the notion of practical intelligence in technology, the “trial and error” and “all or nothing” approaches. The intentional is conversely associated with theoretical intelligence, where each element contributing toward a technological solution can be isolated and analyzed for its effectiveness. A method can be articulated, aligned with the notion of theoretical intelligence in technology, which represents a systematic and deliberate process for the pursuit of new inventions (Ferre, 1995, 40). For example:

- Mental envisionment: What do I want?
- Articulation of theoretical consequences: What would happen if…?
- Construction of an artifact: Will this do it?
- Empirical observation of the outcome: Did it work?
- Comparison: What went wrong?
- Re-articulation of theory: Perhaps this would work?
- Isolation of elements: Was this the problem?
- Modification of the artifact: Now lets see…
- Fresh empirical observation: That works better.

To the extent that this is a realistic process, invention can be encouraged in the classroom. A deeper discussion of the psychology of invention would be necessary to ascertain if the characteristic of invention itself can be taught. But generally speaking, a classroom climate, and an understanding of what constitutes a technology process can both be conducive to the acceptance of invention when it occurs in a classroom.

5. Manufacturing

A manufacturing orientation to technology covers a number of more specific types of processes such as a custom made craft approach, a production line, batch production, and one-off production. In each of these processes, factors to consider include materials, capital, information, transportation, time, and energy. This is an accepted feature of many technology education programs, and continues to be justified because it is an important aspect of real-world technology.

There are many other processes that are used in various technological contexts and could be used by teachers to help represent the breadth of technology to students. For example, repair and restoration, or the development of a business plan, could each be a valid process.

The Teaching of Processes

The variety in pedagogy afforded by the utilization of a range of processes has a number of potential advantages:

- appeals to the preferred learning styles of a range of learners
- makes both teaching and learning more interesting
- more adequately reflects technology

The difficulty in teaching these processes of technology becomes apparent when students are not all doing the same activity at the same time. This means that the students in a class cannot be treated the same as far as teacher attention is concerned. Despite the fact that all students may be working on the same problem, they may be utilizing different processes in seeking a solution, and aiming toward different solutions. Thus, the demands for guidance from the teacher vary. The following are some anecdotal ideas to deal with this situation.

1. Begin with a large group.

In this approach, a situation, problem, or brief is presented and discussed with a class. Then, consensus agreement is reached on a procedural sequence through discussion by class members. After agreement about the approach has been achieved, the teacher can then put a label on each of the activities. For example, "when we looked at similar products on the market, we were evaluating," or "when you asked your friends and neighbors how much they would pay for the product, we were doing market research." The determination of the process is not then dependent on an individual and students begin with the necessity of the activity rather than the possibly meaningless label that goes with it.

2. Don't expect too much too soon from students.

Because the skills involved in technology processes are complex and convoluted, and are different each time a solution to a problem is attempted, it will take a long time to teach the various aspects of processes. It will require even more time for students to practice using those processes selectively and effectively. Lower secondary students should not be expected to proceed individually through a sound and comprehensive self directed technology process. It is not until the upper secondary level that this should be expected to take place.

3. New conceptual and procedural knowledge.

New knowledge must be taught on a need-to-know basis. It is not good enough to tell the students that "teacher knows best, and while the material currently seems irrelevant, there will come a time when it is needed." Because the processes are complex, they should be taught bits at a time. The skill (and most difficult part) of teaching technology is to manipulate students to the point where they realize they need the information you want them to have. The situation should not arise where technology students are stuck in a classroom for the first few weeks of a course because of all the information they need to have in order, for example for them to be able to do design. This will destroy their motivation and enthusiasm for the subject. If students are given information when they realize they need it, their level of retention is higher and they will learn more efficiently.

4. Large projects which last for an extended period of time.

When the students are involved in large projects which last for a period of time, introduce smaller support tasks to give practice in specific skills which can then be immediately applied to the context of the task in which they are working. For example shorter tasks could include the development of a particular graphics skill, practice in identifying peoples' needs, or the identification or manipulation of systems.

5. Minimize the separation of theory and practice.

The continual interaction between the thinking skills and the concrete reality of activity is what enables the development of capability in technology (Kimbell, 1996). But often and in many ways we indicate to students that these two areas are discrete. This separation is evident in:

- timetabling - theory and practical sessions scheduled at different times
- examinations - separate theory and practical exams
- the use and design of work spaces - theory areas and practical areas
- teaching methods - lecturing versus demonstrations.

Students should get the clear message, both through overt and covert strategies, that theory and thinking in technology cannot be separated from technological activity. Either without the other is not representing technology adequately to students.

6. The process can begin at different places.

The point at which the process begins will depend on the outcomes the teacher wishes the students to achieve. It may begin with:

- exposure to a situation, from which students extract a problem,
- a description of the problem,
- a brief already written by the teacher,
- an individual and predefined interest or need,
- an existing product, which is then evaluated for redesign.

7. Support the required skills.

Students must be taught, and then given the opportunities to practice specific skills and techniques before expecting them to incorporate them into a process of technology. Most technology teachers do this well in the area of manipulative skills, but it is also essential for the cognitive skills. For example if we want students to generate ideas, then we need to teach them the skills of brainstorming and morphological analyses. In researching they must be taught survey design or how to use indexes. Specific sketching skills must be taught for them to be able to record ideas. If metacognition is expected, then they need to understand how they think.

8. The sequence of the process.

The point at which the process is initiated may dictate the beginning of the sequence of activities. For example, if a product is to be examined for redesign, then evaluation occurs first; if the activity results from personal need, then the generation of creative ideas may not be necessary. It may be appropriate to prototype ideas early in the process, then go back and revise the brief. As previously stated, there is no set process.

9. The end result of the process may vary.

The most common end result of a design process is a product, but it could just as appropriately be a model or prototype, environment, graphic, system, or service. If a course of study in technology always results in one type of output, there is a danger that the student will develop a limited perception of the nature of technology.

Conclusion

There are many reasons why it is important for students to utilize a range of processes when developing their technological literacy and capability. Technology is such a broad area that a focus on any one process will not provide students with a broad concept of the nature of technology. All students have preferred learning styles, and utilizing a range of processes in teaching technology will appeal to more students than would the use of a single process. It will also make the teaching of technology more interesting to both students and teachers.

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Editorial

Research in Technology Education: What Are We Researching? A Response to Theodore Lewis

Fernando Cajas

Lewis (1999) analyzed the role of research in technology education. He suggested that: “We have to talk about research needs in a way that engenders ever more possibilities. Rather than boxing in the researchers, we must see ways to push the limits and explore new and different frontiers” (p. 52). Here I reflect on Lewis’ recommendations. I concur with several ideas suggested by Lewis, and I propose that the discussion on research in technology education also needs to consider what students should actually learn after they complete their technology education programs.

Lewis stated that the most important questions for research in technology education “probably have to do with challenges encountered by students as they try to learn the *concepts and processes of the subject…*” (1999, pp. 42-43, italics added). I agree, but I would add that an equally important question for research in technology education is what specific concepts and processes of the subject we are talking about. In making my arguments I will focus on three of the eight areas of research suggested by Lewis: (1) technological literacy, (2) misconceptions, and (3) integration.

Technological Literacy

I completely agree with Lewis (1999, p. 43) who suggested that from the perspective of the general public, there is some degree of consciousness on the need for technological literacy. I would add that this should not be the concern of the general public alone, but rather technological literacy should be the main concern of the field of technology education.

According to Lewis, one approach to clarifying the meaning of technological literacy is to study how the term is used. Lewis cites Gagel (1995) who “employed phenomenological strategy, primarily heremeneutics (text analysis), to explore meanings that are ascribed to the notion of technological literacy…” (p. 44). Another approach mentioned by Lewis is to study how adults deal with technological decisions. Lewis cites Welty (1992) who conducted one study of adult behavior, attitudes, and knowledge about technological issues. Although

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such studies could help us to inform our notions of technological literacy, I see two potential problems with them.

First, it will be very difficult to use this information to create technology education programs for *all*, because people will bring different knowledge to any one technology issue. Second, people may not be aware of their use of technology or how to control it. Moreover, people do not often think about technology nor make informed decisions about it. If they were doing so, we would not need a technological literacy movement. More important, the problem of technology literacy is not as much about what people are doing *today,* as it is about what kind of technological knowledge and skills students should have and will need in the *future*. Empirical work may shed some light, but it does not solve the problem. One still needs to imagine the future.

A second approach to technological literacy is to define it. This is not just to speculate about the future, but rather to identify key technological concepts that every body should know. One example of such effort is the work of the International Technology Education Association (ITEA) that has been clarifying the technological knowledge and skills that are needed by all K-12 graduates (ITEA, 1996; 1998). In reading the draft versions of the ITEA standards, one can see that there is a movement toward transforming technology education from craft (practical technology) to more scientific technologies (physical, chemical, biological, and informational technologies). The ITEA standards for technological literacy reflect the problem of how different technology communities are pushing for a place in general education by asking that their knowledge and skills be included in the standards. The authors of the ITEA standards have been generous by including so many areas of technology. But because of this, I think their work lacks focus and coherence. One may ask if research can have a place in formulating the basic knowledge that all students should know to be literate in technology.

First I would say that research might play a role in clarifying what knowledge all students should learn to be technologically literate. However, it is important to note that the basic task here is selecting key ideas of technology that are essential for *all* people in today’s and tomorrow’s world. One way of doing so is by working with expert scientists, technologists, and teachers. The American Association for the Advancement of the Science (AAAS) initiated a process like this through Project 2061. Starting in 1985 and advised by scientists, engineers, technologists, and teachers, the project identified a set of key ideas for technology education (Johnson 1989). These ideas, including a general framework on the nature of technology, were presented in *Science for All Americans* (SFAA), particularly in chapters three and eight (AAAS, 1989). SFAA presents more than a simple aggregate of technological facts. It is a coherent vision of what technology literacy for *all* would mean.

The careful selection of technological knowledge and skills presented in SFAA was a product of several years of discussions. Although it was not the product of empirical research, one can assume that consultants brought research findings to their discussions. Educational research, particularly cognitive research, had a more relevant role in the creation of *Benchmarks for Science Literacy*, known as “Benchmarks” (AAAS, 1993) where the ideas of SFAA were expanded and translated into specific learning goals. Although *Benchmarks* reported that “There is a very small body of research on students learning about what technology is…” (p. 334), it does offer some examples of useful research findings:

- Students can use the engineering model before they can use the scientific model (Schauble, Klopfer, & Raghavan, 1991), and
- Students believe that science affects society in more positive ways than does technology (Fleming, 1987).

One may argue that SFAA and *Benchmarks* have the problem of the “expert” view on technology literacy. However, *Benchmarks* includes several key notions about technology education that are emerging as part of a common ground in many technology literacy movements around the world (ITEA, 1986, 1998; Black & Atkin, 1998; Black, 1998). Some of these ideas are: the relationship between science, technology and society; the notion of design, control mechanisms, materials, manufacturing, sources and uses of energy, information, and systems. These ideas are consistent with recent research in the philosophy of technology and technology education as evidenced in Bunge (1985), Mitcham (1994), Vicenti (1990), Bucciarelli (1994), and Layton (1991).

There are research problems related to technology literacy as proposed by Project 2061 (AAAS, 1989; 1993; 1998). Although SFAA and *Benchmarks* topics have been carefully studied and selected, there is not enough research on how these ideas can be learned and taught. This is research on effective teaching and learning that should illuminate to what extent learning goals on technology education can be achieved. At this point I agree with Lewis on his statement that the most important questions of the field are to study challenges encountered by students as they learn those particular *concepts and processes of the subject*. But to be able to answer these questions, first we ought to clarify these concepts and processes. Take the example of design.

According to Project 2061, all students (adults) after grade 12 should have an understanding of what kind of thought goes into design, particularly the idea that design requires taking constraints into account (AAAS, 1989). There are important questions in working toward this goal. I suggest the following two, in order of their importance. What does it mean that somebody understands that design requires taking constraints into account? How do children learn these ideas and what is the best way to teach them?

What is the notion of design in terms of literacy? From the perspective of literacy, the ability to actually design is not the only important outcome—though designing things can be an important way to learn about design. Some members of society need the ability to design things (e.g., architects, engineers, economists, teachers, etc.), but every individual does not. Literacy involves having all citizens achieve a common core of knowledge and skills beneficial for all of us.

Conceptions or Misconceptions Held by Students

Lewis suggests several examples of the kind of conceptions or misconceptions that can be interesting to study. He proposes, for example, to study what students think about, such as “what happens in an electric circuit when a switch is turned on” (p. 45). Although there has been a lot of research in science education about how students explain electric circuits, particularly with regard to the popular instructional unit “Batteries and Bulbs” (Fredette & Lochhead, 1980; McDermott & Shaffer, 1992), there is not much research about electric circuits in the context of technology education. In implementing technology in elementary education, curriculum developers have found that even teachers who have widely used this unit in science education have problems in interpreting the very idea of switch (G. Benenson, personal communication, March 17, 1999). So the research suggested by Lewis is important, but I would argue that it is not in the study of electric circuits by themselves.

It is difficult to justify knowledge about electric circuits for literacy purposes. If one weighs the time required for successful instruction, as suggested by research, against what can be gained, then electric circuits do not have much to offer to literacy (AAAS, 1999a). Few people will need this knowledge for their lives, since most of the electrical work (e.g., wiring a house) is done by certified technicians, and the use of electric artifacts (e.g., a computer) does not demand this knowledge anyway. However, behind the notion of an electric switch are important technological ideas about *control systems* that are fundamental for literacy. It is important to know about control systems because they influence the behavior of people and things. In its recommendations about control systems, *Benchmarks* suggested that: “An idea to be developed in the middle grades is that complex systems require control mechanisms. The common thermostat for controlling room temperature is known to most students and can serve as a model for all control mechanisms” (AAAS, 1993, p. 50). However, the idea of complex systems is extended beyond physical systems: “Students should explore how controls work in various kinds of systems—machines, athletic contests, politics, the human body, learning, etc.” (ibid., p. 50). In short, an electric switch can be seen as one context for learning more important technological ideas, particularly ideas about *control systems*.

After having suggested a rationale to include electric circuits as a context of key technological ideas (complex systems), it is important to note that there is almost no research on how children learn how control systems work, and there is even less research on how teachers can teach these ideas. In fact, when students are working with their electric circuits, such as the Batteries and Bulb unit, one can sadly say that they are not being taught what is most important, that is, how complex systems work.

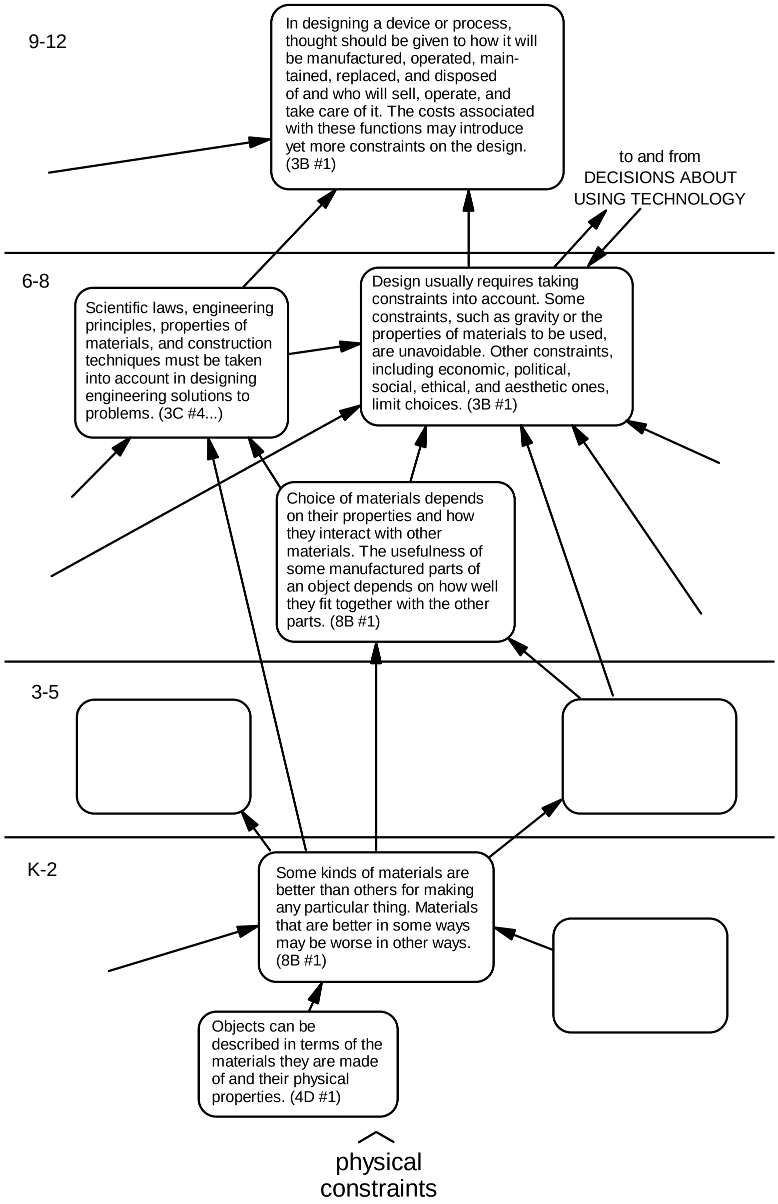
The second example presented by Lewis has to do with students’ conceptions regarding “how standard metal bars and rods get their shapes” (Lewis, 1999, p. 45). Again, it is important to clarify that learning about the specific properties of specific metals is not very important for literacy purposes since only certain members of society need this specialized knowledge (technicians who have to deal with metals, some kinds of engineers, some kind of artists, etc.). However, there are general ideas about materials that everyone should know (AAAS, 1989; Amato, 1998). For example, a K-2 benchmark states that: “Some kinds of materials are better than others for making any particular thing. Materials that are better in some ways (such as stronger or cheaper) may be worse in other ways (heavier or harder to cut).” (AAAS, 1993, p. 188). The justification of why this is an important idea for technology literacy requires recognizing where it comes from and where it leads students. In order to illustrate this point, consider a section of the Project 2061 map called Design Constraints (Figure 1). The map lays out conceptual strands (e.g., physical constraints) that develop over time with increasing sophistication and connections across topics.

Before students can learn that some *materials* are better than others, it is important to work with them in distinguishing between objects and the properties of the *materials* of which they are made. In Figure 1 this is the connection presented before the learning goal that states that “Some kinds of materials are better than others…” (K-2 level).

In my own current work with schools, I find that children (and teachers) have problems distinguishing the properties of the objects (e.g., this sheet of paper has a rectangular shape) from the proprieties of the material that made the objects (e.g., the flexibility of the paper). In fact, research has shown that “The tasks of classifying objects according to what they are made of and of comparing properties of materials can be challenging for early elementary-school children. In addition, elementary children may have limited knowledge or hold misconceptions about the origins and transformations of materials” (AAAS, 1993, p. 349, Russel, Longden, & McGuigan, 1991).

Since the work of Piaget, science educators have explored how children describe materials in terms of their physical properties. Because science education has different goals than technology education, research in science education has focused on how children describe physical properties. From the science education perspective, descriptions of physical properties of objects are the basis for understanding later important idea s such as conservation of matter, states of matter, and chemical reactions. What are the important technological ideas we want students to learn with their understanding that some materials are better than others? How relevant is this science education research for technology education? We cannot discuss the relevance of this research if we do not know what we want students to learn at the end of their K-12 technology education.

What do students need to know in order to understand ideas related to materials, particularly that some materials are better than others (K-2 level)? Research in science education on how children learn about materials and their properties may serve as a starting point. However, this research has not explored “functional” properties of materials (i.e., properties of materials based on their use such as those suggested by *Benchmarks*: strength, stiffness, hardness, and flexibility). There is almost no research on how students learn these ideas. In the context of the map, ideas about materials in grades K-2 are the basis for learning about design at higher levels. Students should understand that design requires taking constraints into account, some of which have to do with the properties of the material to be used (AAAS, 1993, p. 51, see Figure 1, box 3B#1 at 6-8 level). Although there are some high school curriculum guides that have



In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (3B #1)

Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems. (3C #4...)

Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of materials to be used, are unavoidable. Other constraints, including economic, political, social, ethical, and aesthetic ones, limit choices. (3B #1)

Choice of materials depends on their properties and how they interact with other materials. The usefulness of some manufactured parts of an object depends on how well they fit together with the other parts. (8B #1)

Some kinds of materials are better than others for making any particular thing. Materials that are better in some ways may be worse in other ways. (8B #1)

Objects can be described in terms of the materials they are made of and their physical properties. (4D #1)

Figure 1. Map of Design Constraints from AAAS – Project 2061 (draft)

introduced ideas about materials (e.g., Hsu, Walhof, & Turner, 1996), there is no work on the introduction of these ideas over a K-12 plan for technology education. There is almost no research on how children learn these ideas and how teachers could teach them.

Integration

Integration is a word that produces sympathy in educational circles. However, as Lewis said, the field of technology education has to understand integration better (p. 49). Lewis developed a rationale to study how integration can help improve technology education. He suggested important research questions such as whether integration of technology with other subjects may help improve students' learning of technological concepts and processes. Another question is related to the models of integration that bear the most promise (p. 49). Although I think that these are valid questions, I believe that the problem of integration is not a problem of research alone. First, integration is a political decision. Second, we cannot be clear about integration if we do not know *what* we are going to integrate.

Let us take the example of the integration of science with technology. There has been some research, mostly from the science education perspective, on how to integrate science with technology. For example, in the 60's Renners studied how students understand the relationship between science and technology (1963). In the 90's, to mention one example, Roth has widely reported his work on how children learn science via technology (e.g., 1998, 1997, 1996a, b. See also Kamen, Roth, Flick, Shapiro, Barden, Kean, Marble, & Lemke, 1997; Schauble et al., 1991; Carey, Evans, Honda, Jay, & Unger 1989; *Benchmarks*, Chapter 15). Recent reports have acknowledged the difficulties that science teachers are having with such integration, i.e., connecting science with technology education (Hepburm & Gaskell, 1998; Bark & Pearlam-Avnion, 1999).

The basic problem I see with this "integration" is that it focuses mostly on science and only incidentally on technology. Technology is addressed only as a means to teach and learn science. It is true that technology can provide contexts to learn science as well as other subjects, but from the perspective of technology education the fundamental aim is to secure a permanent place in general education. What is urgent to understand is that there are important technological ideas that all should know. It does not immediately matter how we want students learn them, whether it be through integration or not. Integration, although important, should not be our priority now. The importance of technology in general education should not be dependent upon its integration into science, mathematics, or other subjects.

Concluding comments

Let us now step back and review my proposal. I have discussed Lewis' assumptions more than any specific suggestions he offered for research in technology education. This is because I think there is an essential prior question to be answered: What knowledge and skills should everybody know? Why is this an important question? Because contemporary society, as well as the society of the next century, depends heavily on technology. It is our responsibility to present a common argument to bring technology to the classroom. Such an argument demands that we clarify what we are trying to achieve. That is, what ideas and skills all people need to understand about technology to be able to participate in a technological world in a thoughtful and informed manner. This common ground should drive the need for and direction of research in the movement toward providing technology education for all. Without such a consensus, research in technology education and the efforts to bring technology into the school curriculum will remain an incoherent, fragmented, and ultimately ineffective endeavor.

Note: The map included in Figure 1 is closely connected to another map titled "Designed System," which is not included herein. The included map has been simplified from the original to more clearly support the argument made. It is suggested that the reader review the complete maps once they are published (AAAS, 2000b).

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Nadin, Mihai. (1997). ***The Civilization of Illiteracy*****. Dresden, Germany: Dresden University Press, Inc. $79 (Hardcover), 880 pp.**

Reviewed by Stephen Petrina

Literacy and illiteracy are no longer what they used to be. This is basically the conclusion of Mihai Nadin in his *Civilization of Illiteracy*. Nadin traverses over a few thousand years of the history of literacy, but the bulk of his attention is turned toward the contemporary. Now, he writes, we are witnessing the proliferation of literacies and multiplication of media on a scale that makes notions of a single form of literacy seem like a quaint dream of the past. The *Civilization of Illiteracy* is a documentary record of literacies and their forms which are circulating through the urban and hyper-urban creations which we have come to call our modern Babylon. Nadin may be out of vogue in his long, historical view of literacy, in his wordiness at a time when three-sentence paragraphs are an Internet average, and he may be out of vogue in his refusal to select any single specialized lens with which to analyze our Babylon. This break from academic and popular fashion is precisely what makes his work so far-reaching. However, there are big differences between authors and rhetoricians, and I could argue that his message will be lost in the painstaking details of the *Civilization of Illiteracy*. This argument would ignore the message and Nadin's medium is the message. Reduced to 880 pages of text without a single chart, comic, doodle, drawing, graph, icon, photograph, or sketch, our modern Babylon is in a book. There is only black print on white pages. Swoosh - nothing but text - pure text. If this is some kind of post-modern joke, I would finish the review at this point. To be sure, there is quite an irony in his choice of media—in his reduction of modern Babylon to Babel to text—but I assure you, Nadin is serious, if not seriously post-modern.

Literacy is no longer a key to cultural participation in what has become an "illiterate" civilization. Literacy for Nadin is not merely the ability to read, write, and decipher text, but rather a cultural way of being. Indeed, being literate is about the same as being "modern." The privileged status of this particular way of being can no longer be maintained Nadin argues (pp. 8-11, 140). Literacy is all-encompassing as he demonstrates, reaching beyond communication or education, and far into aesthetic, athletic, commercial, religious, sexual, and

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technological practices. But he is quick to note that literacy as a way of being has been undermined by a number of other literacies, or simply by illiteracy. Participating in these types of practices no longer requires that one be “literate” in the traditional sense. Hence, the more one argues for widespread ecological, scientific, technological, or visual literacy, the more one acknowledges the fall of literacy and the reign of illiteracy.

Some design and technology educators may be attracted to visions of a digital future in *Civilization of Illiteracy* (pp. 729-767). What makes the World Wide Web so promising says Nadin, “is not the potential for surfing, or its impressive publication capabilities, but the access to the *cognitive energy* that is transported through networks” (p. 740). Other design and technology educators may take to his descriptions of the interrelations between design and literacy (pp. 590-613). “[T]he new object is designed to be idiot-proof (the gentler name is *user-friendly*)” he notes, “reflecting a generalized notion of permissiveness that replaces self-control in our interaction with artifacts” (pp. 610-611). I am much less hopeful than he is in the potential of intelligent materials and machines to address our ecological problems (pp. 603-604). Still other educators may resonate with his prescriptions for education (pp. 282-318, 746-751). “The change from a standardized model” of education he argues, “to the collaborative model of individuality and distinction re-establishes an ethical framework…The goal of education cannot be the dissemination of imitative behavior, but of procedures” (pp. 316, 746). For readers of the *Journal of Technology Education,* the three chapters on digital technologies, education, and design are the most relevant among the twenty-three chapters in the book.

Nadin offers an accurate portrayal of the complexity of navigating in and around Babylon—a civilization spoiled in luxury and vice. While the proliferation of literacies ought to be documented, it is not clear that this ought to be celebrated. To be sure, it can be argued that this proliferation is not so much a flowering of diversity as it is a reassembling of Babel, but now in the form of Babylon. Multiple literacies certainly do not offer a common ground for dialogue. Multiple literacies in no way offer a collective medium for discussing what it is that we all have in common, or how we might go about establishing a way toward a common future. Then again, there is the possibility that we have never been literate: there was never a time when spoken and written language literacy reigned over others (Latour, 1991). We were always a hybrid of illiterate and literate objects and subjects. So for now, I’m opposed to celebrating illiteracy as a post-modern accomplishment *ala* Nadin, and prefer the project of dismantling Babylon and rebuilding literacy from the collective ground up (Petrina, in press).

References

Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.

Petrina, S. (in press). The politics of technological literacy. *International Journal of Technology and Design Education*.

Miscellany

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The *Journal of Technology Education* provides a forum for scholarly discussion on topics relating to technology education. Manuscripts should focus on technology education research, philosophy, and theory. In addition, the *Journal* publishes book reviews, editorials, guest articles, comprehensive literature reviews, and reactions to previously published articles.

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Errata

The following correction for Vol. 11, #1, Fall 1999 issue:

In the “Table of Contents,” second article, authors are Aaron C. Clark AND Robert E. Wenig.

Our apology to Robert E. Wenig for the omission of his name.

Colophon

All manuscripts for this issue of the JTE were received from the authors in digital format and reformatted with Microsoft Word 8.0. Page galleys were output to an Apple LaserWriter 16/600PS and printed at the Virginia Tech Printing Center.

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