Journal of Technology Education

Volume 11 Number 1 Fall, 1999

Journal of Technology Education

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ISSN 1045-1064

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From the Editor

Herding Cats in the Midst of the Swinging Pendulum

Historians adamantly adhere to the notion that the best way to understand the future is through understanding the past. This is based, at least in part, on the fact that history tends to repeat itself. A corollary to this in education is the analogy of the swinging pendulum. When I began my teaching career some 33 years ago, the pandemonium that resulted from Soviet leadership in the space race, as manifested by the successful launch of the satellite Sputnik, had begun to ebb. The pendulum had started to swing away from highly structured curricula, based to a large extent on behaviorist theory. It also began swinging away from the concomitant emphasis on mathematics and science.

As the pendulum continued its cyclical journey past the midpoint, emphasis was increasingly placed on a more flexible form of education, perhaps in some respects a reincarnation of the original ideals of a liberal education; that is, an education that liberates the mind from the toil of everyday life. The emphasis was on the humanities and social sciences. Personal development, creativity, and self-expression were highly regarded. The leisure time purpose of industrial arts that some thought was the most significant impediment to a legitimate and defensible curriculum, grew in prominence and acceptance.

In many forward-looking schools, students were given the opportunity to custom-design their own educational experiences by selecting from a menu of “modular” courses of varying lengths that would best meet their personal interests. “Open” school designs, in which there were no walls separating classes, were constructed. Due to lofty idealism that was not properly tempered by practical reality, the pendulum began to swing the other way. It was accelerated by the poor performance of United States students on internationally standardized tests in mathematics and science. This led to, among other things, an emphasis on standards of learning and achievement test performance.

The pendulum has probably not yet reached the full extent of its swing toward a highly structured, accountability-driven curriculum. Elective courses in art and music are still struggling for enrollment, for example. But if we believe in the tenets of historians, in due time the pendulum will reverse its direction and begin, once again, its inevitable travel in the opposite direction.

The swinging of the pendulum from one philosophical extreme to the other provides balance of thought and well being to our social and political systems, just as the swinging pendulum provides a balance of forces and allows a clock to operate properly. One of the differences, though, in today’s swinging pendulum is the computer. It will no doubt uniquely and dramatically influence the outcome of the cycle. Though the research evidence is somewhat contradictory at the present time, there is little doubt that educators will begin to reach consensus on the most effective ways in which to use computers for teaching and learning.

Technology education has embraced computer use in a variety of different ways, arguably with more divergence than any other subject in the school. Computers have most certainly enabled us to do a variety of new and exciting things that we have never been able to do before; they are interactive and "hands-on." For many of the other subjects in the school, computers have resulted in a more active and individualized learning environment. But from a relative perspective, computers in technology education have resulted in a more sedentary, passive experience for students. For example, computers play a pivotal role in nearly all of the modular programs that are sweeping across the U.S. and other countries as well. In many of these programs, the students remain largely seat-bound for the majority of the instructional time. In this issue, Gustafson, Rowell, and Guilbert describe the perceptions that elementary students have about structures. The technology now exists that enables students to design, build, and test such structures in the virtual reality of the computer without ever leaving their seats. "Activities" of the past are rapidly becoming "passivities."

The excitement that has resulted from the use of computers is refreshing and engaging. But the dynamics of the change causes one to ponder. As we continue to discard the tools that we used in the past in favor of computers, are we ignoring some of the fundamental developmental needs of the students we serve? Is there something to the hesitancy in curriculum change that the teachers in Finland exhibited, as reported by Alamaki in this issue? Have we put technological content in such a primal position that we are ignoring process, the dichotomy that Lewis addresses herein? Is there something very unique that occurs developmentally when students work with real tools and materials? Are such experiences tantamount to successful, meaningful problem solving, as Atkinson's (1999) work in the last issue suggests? Could it be that those experiences contribute significantly to the development of the individual, but have virtually nothing to do with technology education as we have defined it nor the outcomes we think we are achieving? And if all of this is true, is there an age at which such activity is no longer appropriate?

Some wag might one day soon think about how sedentary life has become with the proliferation of the computer into every aspect of our existence, from school to the work place, from religion to entertainment. That person might think about the unique sense of satisfaction that comes from creating something with one's own hands, and that this is a fundamental need of humans. That person might further become concerned about how people spend their leisure time in this electronic age. As history repeats itself, the wag might even reinvent the other six Cardinal Principles of Secondary Education (1918) without even realizing it!

One of the administrators with whom I worked described the management of college professors as analogous to trying to herd cats. Perhaps the elements of our content, as well as our methodology, are akin to the cats. And, like cats, there are more of them every time you turn around. There is a limit, though, to how many cats we can take with us on that swinging pendulum. We have to decide which ones we will choose. We may decide to continue to leave in the closet the cats representing worthy leisure time activity, psychomotor skill development, consumer literacy and other vestiges of our past. But one way or another, someone will see to it that all the cats will somehow get to the other side as the pendulum swings.

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JEL

Articles

Technology Education in the Finnish Primary Schools

Ari Alamäki

Introduction

Technology Education in Primary School

This study focuses on the practices and potential of technology education in Finnish primary schools, where technology education is a compulsory school subject. As in many other countries, the content of technology education is currently being discussed and debated in Finland. For example, Autio (1997), Kananoja (1997), Kankare (1997), Kantola (1997), Lind (1996), and Parikka and Rasinen (1993) argue in their studies that more up-to-date technological content is needed.

Finland has a long tradition of teaching practical school subjects. Since 1866, educational handwork (sloyd) has been a compulsory school subject for both boys and girls (Kantola, 1997). Finnish technology education, called "technical work" in the national curriculum guidelines, is a school subject in which pupils design and make products by using different materials, machines, processes, techniques and tools (e.g. Kankare, 1997). This emphasis on designing and making is an essential part of Finnish technology education. It is believed that such experiences develop pupils' knowledge, personal qualities, and psychomotor skills (Peltonen, 1995; Suojanen, 1993). As with the traditional (sloyd) programs that preceded it, there is general belief that the design and build approach used in contemporary technology education programs enhances the pupils' creativity, dexterity, diligence, initiative, problem solving, self-image, and preparation for work.

As technology education has evolved in Finland, more content has been introduced, including such areas as electricity, electronics, machinery, and computers. Construction kits for teaching control technology have also been adopted. In addition, technology education classes now offers pupils the opportunity to service and repair their bicycles, mopeds, and other technical equipment. These areas, combined with the more traditional sloyd (craft and design), have made Finnish technology education more diverse than in other Scandinavian countries.

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In informal discussions among teachers and teacher educators, there seems to be a general feeling that technology education in Finnish primary schools is out of date, emphasizing older technological processes such as the making of wooden and metal items. Even though technology education has been updated to an extent, there is a general feeling that there should be more connection to the modern technological world than that which exists presently. The technological concepts of communication, construction, energy, manufacturing, and transportation are rarely reviewed from ecological, economical, cultural, and social viewpoints. The activities in which the pupils are engaged determine the kinds of technological knowledge and processes they learn. These activities must therefore be upgraded.

The Finnish School System

The Finnish comprehensive school provides compulsory basic education to pupils between the ages of 7 and 16. It is divided into a six-year lower level (grades 1-6), which corresponds internationally to primary education, and a three-year upper stage (grades 7-9), corresponding to lower secondary education. This study focused on technology education at the primary school level, where pupils are between 7 and 13 years old.

In the third grade of the primary school, it is compulsory that all pupils study technology education. After that they have to choose either technology education or textile work. As one might expect, boys usually choose the former and girls choose the latter. Pupils who have chosen technology education study it for at least two hours a week from third through sixth grades.

In Finnish primary schools, technology education is usually taught by regular classroom teachers. Today these teachers must hold a master’s degree in education and most have studied technology education as part of their teacher preparation program. A separate technology education room is provided for instruction, with an ideal maximum of 16 students in the facility at one a time.

The national curriculum reform in 1994 gave schools noticeably more freedom in developing their own curricula (Kohonen & Niemi, 1996). The national core curriculum and curricular guidelines are very vague, providing only brief outlines. Though this allows for local flexibility, it also increases the diversity in the way in which technology education is taught from one school to another. In the latest national core curriculum, the main emphasis is on the “idea-to-product” process, with the pupil fully engaged in designing (Opetushallitus, 1994). Although, the designing and making of products remains as the central part of the national curriculum guidelines, the need for a broader technological understanding and capability is also mentioned.

Research Questions

The research questions of the study are summarized as follows:

1. What kinds of teaching practices are there in technology education in primary school? This question was intended to elicit information, for example, on the extent of computer usage in technology education now and that expected in the future, the extent of cooperation with local

industry, and the kinds of tasks performed by students in technology education.

2. What goals of technology education are accomplished in primary school? This question focused on the extent to which the goals of the national curriculum were being realized. This included product design-based work and the extent to which students were copying designs rather than actually developing designs themselves. Information on the teaching methods used to teach design was also investigated.

Demographic data about the age of the teacher, educational background, and teaching experience were collected so that comparisons could be made. Secondarily, this study investigated how teachers define the word technology, perceived obstacles to the development of technology education, and the ideal way in which teachers would like to view technology education.

Method

Instrument

The research questions were addressed by means of a survey instrument. The main part of the instrument was modeled after instruments used in two other technology education studies (see Alamäki, 1997; Kankare, 1997). These initial instruments were shown to be acceptably valid. There was no reason to believe that the teachers would not answer truthfully. They answered anonymously and it is plausible that they viewed the questionnaire as a way for them to contribute to the development of technology education. The majority of the questions were close-ended, requiring responses on a five-point scale with the following descriptors: “never,” “seldom,” “some extent,” “often,” “very often.” The responses were assigned numerical values from 1 (never) to 5 (very often). A few open-ended questions were also included.

Sample

The study was conducted in the Finnish provinces of Oulu and Varsinais-Suomi. The former lies in northern Finland and the latter in the southwestern region. The instrument was mailed to a sample of 300 primary schools, stratified by geographic region, in the spring of 1997. One technology education teacher at each school was selected as the contact person. At the beginning of the following school year, another copy of the questionnaire was sent to non-respondents. After these two mailings, 212 (70.7%) completed questionnaires were received. By geographic strata, 104 of the responding teachers were in city schools, 28 in provincial towns, and 80 in rural areas. The data showed that the vast majority (205) of the teachers in the study were male.

The average age was 41.1 years (*SD*=10.05). The average amount of teaching experience was 15.8 years (*SD*=10.22 years), with 14.6 years (*SD*= 9.92) spent teaching technology education. On average, the respondents taught technology education 5.3 hours (*SD*=4.79) per week. Twelve of the teachers held a degree in technology education and all of the respondents except five had a bachelor’s or master’s degree in education. Ten of the teachers worked as technology subject teachers, whereas the remainder of them worked as regular classroom teachers. All had studied technology education in the teacher preparation program since such study is compulsory.

Procedure

The close-ended questions were analyzed quantitatively by using frequencies and averages. Chi-square testing, one-way ANOVA and Pearson correlation analysis were also applied to selected responses. The “copying teaching method” and the “design teaching method” were compared using a dependent sample t-test. The reliability coefficients of the variables concerning the goals of teaching and the teaching method ranged between .61 and .83 and were deemed acceptable. The open-ended questions were also analyzed quantitatively by using descriptive statistics, grouping similar responses together.

Results

Practices in Technology Education

The first section of the instrument focused on the use of computers in teaching technology education now and in the future. It included two close-ended and one open-ended questions. Analysis revealed that 15% of the respondents had the potential of using a computer in technology education and 32% felt that they would have this potential in the near future. There was not a statistically significant difference in the potential of using a computer among cities, townships and rural areas, either presently or anticipated in the future. The predominant use of computers in technology education was for drawing and planning. Use of the World Wide Web or software developed for educational purposes was rarely mentioned.

Cooperation with local industry was examined with both closed-ended and open-ended questions. Nineteen percent of the respondents indicated that they have cooperated with local industry. In most cases, this involved the donation of materials or the provision of student field trips. Examples of the latter include visits to a sawmill, a fiberboard factory, and a fishing lure manufacturer. In some cases, the teachers also received expertise from the local industry. No differences were found among geographic strata.

The study also investigated the kinds of activities used in technology education and their suitability to students at the primary level. Respondents were asked to rate nine selected activities. A description of each activity was provided. For example, it was explained that in the activity “woodworking,” wood was the primary material with which the students worked. Regarding electrical equipment, it said that this activity included such topics as transistors, IC-circuits, and construction kits for teaching electronics. Familiarity with technological equipment included such elements as exploring the functional principles of radios or computers; service and repair included topics such as the maintenance of students’ bicycles and other equipment. These data are reported in Table 1.

Table 1
Extent of Use of Selected Activities in Primary School Programs

	Extent of Use							
			Some-		Very			
	Never	Seldom	times	Often	often	Total		
Activities	*f* (%)	*f* (%)	*f* (%)	*f* (%)	*f* (%)	*f* (%)	*M*	*SD*
Woodwork	1(1)	0(0)	11(5)	92(44)	107(51)	211(100)	4.44	.64
Service and repair	11(5)	46(22)	111(53)	33(16)	9(4)	210(100)	2.92	.87
Metal work	10(5)	60(29)	100(48)	36(17)	4(2)	210(100)	2.83	.84
Plastic work	14(7)	60(29)	88(42)	45(21)	3(1)	210(100)	2.82	.89
Electro-mechanical equipment	20(10)	78(37)	88(42)	22(10)	3(1)	211(100)	2.57	.96
Electronic equipment	44(21)	55(26)	75(36)	31(15)	5(2)	210(100)	2.51	1.05
Familiarity with technological equipment	124(59)	52(25)	26(12)	5(2)	2(1)	209(100)	1.61	.87
Construction kits	135(64)	51(24)	20(10)	3(1)	2(1)	211(100)	1.51	.80
Internal-combustion engines	131(62)	56(27)	18(9)	5(2)	0(0)	210(100)	1.50	.75

Woodwork was clearly the most popular technological activity in Finnish primary education. The next activities in terms of popularity consisted of plastic work, metal work, service and repair of technical equipment and vehicles, electric-mechanical equipment, and electronic equipment. Least popular were construction kits, internal-combustion engines, and familiarity with technological equipment. In addition to the nine listed activities, respondents were asked to list one other activity. Leather, rattan, mosaic work, and building model airplanes were among those listed most often. When age, education, school location, and work experience were considered, the only statistically significant result was that those teachers who hold degrees in technology education use more activities that are related to electro-mechanical equipment than those who did not hold such degrees (p=.01).

The teachers generally felt that all of the nine prescribed activities could be suitable for technology education at the primary level (see Table 2). Woodworking was considered the most suitable (and the most popular); 72% of teachers stated that it is a very well suited activity for technology education. In addition, the teachers felt that activities such as service and repair, electronic equipment, electric-mechanical equipment, plastic work, and metalwork were well suited to the primary level, although they did not teach them often. The teachers, however, supportive of the suitability of activities related to techno-logical equipment and internal-combustion engines. When age, education, the location of school, and work experience were considered, it was found that there were not any statistically significant differences that had relevance to the study.

Table 2
Suitability of Selected Activities to Primary Level Technology Education

	Level of Suitability							
Activities	Not at all *f* (%)	Poorly *f* (%)	Neu-tral *f* (%)	Well *f* (%)	Very well *f* (%)	Total *f* (%)	*M*	*SD*
Woodwork	0(0)	1(1)	9(4)	48(23)	150(72)	208	4.67	.58
Service and repair	0(0)	7(3)	54(26)	87(42)	59(29)	207	3.96	.83
Electric-mechanical equipment	1(1)	8(4)	56(27)	96(47)	45(22)	206	3.85	.89
Plasticwork	1(1)	12(6)	64(31)	96(46)	34(16)	207	3.73	.82
Metalwork	0(0)	12(6)	71(34)	91(44)	33(16)	207	3.70	.81
Electronic equipment	7(3)	18(9)	57(28)	82(40)	42(20)	206	3.65	1.00
Construction kits	8(4)	16(8)	87(42)	72(35)	22(11)	205	3.41	.92
Familiarity with technical equipment	24(12)	65(32)	74(36)	31(15)	11(5)	205	2.71	1.03
Internal-combustion engines	27(13)	65(32)	74(36)	29(14)	9(4)	204	2.65	1.02

The Goals of Teaching

The Finnish curriculum guidelines mention creativity, cultural heritage, environmental education, entrepreneur education, self-image, problem solving skills, social skills, and readiness for work life as the general goals of a comprehensive education. This study investigated how these general goals were manifested in technology education. The responding teachers were asked to describe the extent to which pupils’ activities in technology education corresponded to the goals.

According to the results reported in Table 3, technology education focuses most on students’ creativity. The development of problem-solving skills, self-image, cultural heritage, and social skills are also often associated with technology education. However, readiness for work life, environmental education, and entrepreneur education are associated to only a limited extent with technology education according to the responding teachers.

In addition to general goals, this study also considered activities related to product design. Product design strongly emphasizes creating products, such as that suggested in the “idea-to-product” processes mentioned earlier. Traditional product design-based work includes the development of manual dexterity, product planning, work safety, work education, and aesthetic education. The results indicated that manual dexterity was most central to the product design-based work. In addition, work education, work safety, and product planning were considered essential components. Aesthetics were considered to be a limited part of teaching and the pupils’ work.

The study also included an assessment of the three dimensions of technological literacy as espoused by Dyrenfurth and Kozak (1991) and others: the utilization of technology, the evaluation of technology, and the appreciation of technology. The utilization of technology refers to the acquisition of the knowledge and skills necessary to use and make technological products and solutions. The evaluation of technology refers to the critical evaluation of the impact and consequences of technological processes. The appreciation of technology refers to understanding the outcomes of technological innovations as they relate to a higher standard of living. The data in Table 3 indicate that the respondents feel that technology education is most concerned with the utilization of technology and that the evaluation and appreciation of technology are of lesser significance.

Table 3
Educational Goals and Dimensions Realized Through Technology Education

	Never	Little	Some extent	Much	Very much	Total		
	f (%)	*f* (%)	*f* (%)	*f* (%)	*f* (%)	*f*	*M*	*SD*
The general goals of primary education								
Creativity	1(1)	3(1)	53(25)	113(54)	41(19)	211	3.90	.73
Problem solving skills	0(0)	14(7)	61(29)	114(54)	20(10)	209	3.67	.74
Student's self-image	2(1)	10(5)	78(37)	90(43)	29(14)	209	3.64	.82
Social skills	0(0)	19(9)	81(38)	95(45)	16(8)	211	3.51	.77
Cultural heritage	2(1)	14(7)	85(41)	91(43)	17(8)	209	3.51	.78
Work life	4(2)	39(18)	90(43)	66(31)	12(6)	211	3.20	.87
Environment education	8(4)	57(27)	104(49)	39(18)	4(2)	212	2.88	.82
Enterprise education	19(9)	77(37)	84(40)	26(12)	4(2)	210	2.61	.89
The product design based goals								
Manual dexterity	0(0)	1(1)	5(2)	86(41)	119(56)	211	4.53	.57
Work education	0(0)	4(2)	34(16)	106(50)	68(32)	212	4.12	.74
Work safety	0(0)	1(1)	39(18)	118(56)	54(25)	212	4.06	.68
Product planning	0(0)	4(2)	87(41)	96(45)	25(12)	212	3.67	.71
Aesthetics	1(1)	16(7)	90(42)	99(47)	6(3)	212	3.44	.70
The dimensions of technological literacy								
Utilization of technol.	1(1)	12(6)	92(43)	98(46)	9(4)	212	3.48	.69
Evaluation of technol.	4(2)	45(21)	115(54)	44(21)	4(2)	212	3.00	.76
Appreciation of technol.	4(2)	66(31)	101(48)	39(18)	2(1)	212	2.85	.77

One approach used in technology education involves students in the making of artifacts using prescribed drawings or plans. In this study, the aforementioned approach is referred to as the "copying teaching method." Pupils can also invent, design and make products by themselves. This second method is referred to as the "design teaching method." Five statements with a five-point scale focused on each teaching method. According to the results, the teachers use the design teaching method significantly more (p<.001) than the copying teaching method. The means were 3.12 and 2.85 respectively. Thus technology education in primary school is more design-oriented.

The Obstacles to the Development of Technology Education

The study investigated obstacles to developing technology education in primary education with both closed-ended and open-ended questions. The respondents indicated that the three most significant obstacles, in order, were:

1. Lack of financial resources.
2. Insufficient material on how to teach technology education.

3. Lack of other accompanying resources.

The lack of financial resources determines what type of teaching materials may be purchased. In turn, this relates to the teachers' perceptions about delivering a valid technology education program. One teacher, for example, stated, "Can anybody manage to develop technology education in a positive direction with these kinds of financial resources?" The lack of financial resources was followed by the lack of teaching ideas and the lack of other accompanying resources. The latter is related to classroom tools, machines, and other equipment that must be purchased with resources other than those used for supplies and materials. No significant differences among the respondents were found for the top three obstacles listed above. Though not at the top of the list, motivation was one of the obstacles identified. It was found that older teachers felt that they had significantly less motivation compared to younger teachers (p<.05).

The Development of Technology Education

Perceptions about technology education in the future were also investigated in this study. An open-ended question asked the respondents how or in what direction they would like to see technology education change in the future. Over one-fourth of the respondents felt that program updating was the most important goal to pursue in the future for the development of technology education. Samples of the respondents' statements with some caveats included, "…modern technology must be included in the right amount in the curriculum in such a way that it does not become an end in itself" or "More technology should be generally forced into the comprehensive school. But it can not take away from the diminishing number of handwork specialization courses…people have a need to do work with their hands…".

Eighteen percent of the respondents felt that the making of products should continue in the future. Several connected this perception with the need to bolster the content as well. There seemed to be a strong sentiment about moving toward a changed program but not discarding critical elements of traditional programs. Examples of statements supporting this were:

- "I appreciate the teaching of handiwork tradition and the applying of technological integration…Therefore, teaching of technological understanding is already entitled to start from childhood."
- "The diversified use of different materials, new work methods, and technology should nonetheless be realized without losing traditional woodworking."
- "Generally more technology to the comprehensive school, but this may not take time from more and more important dexterity…".
- "In technology education the final product is also important. The subject may not only be going toward technological knowledge. The making of concrete articles is very rewarding for many kids…".
- "Certain basic skills, techniques and traditional tasks should be saved, but stressing technology education could be moved toward so-called new teaching of electronics."

Diversification of curricular content to increase breadth was mentioned by 17% of teachers. Sample responses included, "Technology education should strive toward diversification" and "more diverse content is needed." Modernizing programs was mentioned by nine percent of the respondents. The term modernizing in this context refers to the need for programs to reflect contemporary society. A sample response in this category was, "More connection with these modern times." Nine percent of the teachers mentioned creativity, such as: *"Move away from wood, toward creativity and new materials"* or, simply, *"More creativity."* Teaching basic skills, electronics, planning, and the traditional handwork were also mentioned, but to a lesser extent.

Table 4
Goals for the Future Development of Technology Education (n=118)

	f	%
More technological content	32	27
The making of products (handwork)	21	18
Diversification of Curriculum	20	17
Modernizing Curriculum	10	9
Creativity	10	9
Other	85	72
Total	178	--

The Concept of Technology

The study sought to determine teachers' perceptions of the word technology by asking them to write a definition for it. Due to the breadth of the responses, some of the definitions were placed in more than one category. These data are reported in Table 5.

Table 5
Teachers' Definitions of Technology (n=170)

Definitions	f	%
Utilizing technical devices	61	36
Knowledge, skills, and means for doing different tasks	56	33
Technical devices and machines (artifacts)	38	22
Production process	25	15
Knowledge of how technical devices and machines work	8	5
Others	45	27
Total	233	--

Over a third of the teachers defined technology as the utilization of technical devices. The teachers in this group tended to emphasize the practical purposes of technology. Examples of definitions in this group included "work which is accomplished with machines" or "the use of technical devices instead of muscular strength."

One third of the teachers defined technology in terms of human knowledge and capability relative to accomplishing tasks. Technology was seen as know-how, or "human capital," which helps humans satisfy their needs and wants. Examples of statements in this category are "the adapting of modern technical know-how for the needs of humans" or "an activity which is realized with the help of thinking and equipment in practice."

Nearly a quarter of the group thought of technology in terms of artifacts. Sample definitions include "devices and machines which help the work and activity of humans" and "today's high technology consumer products, such as mobile phones, computers, gauges, etc." Technology was understood as a production process by 15% of the responses. Included in the "other" response category were concerns about the elimination of existing content such as, "the killer of a traditional handwork…or at least a big threat" and "everything involving dexterity is technology."

Discussion

Woodwork is the most popular activity area in technology education in Finnish primary schools. Electricity and electronics tasks, plastic work, and service and repair are taught to a certain extent. Nonetheless, all of the activities listed in the study were considered suitable for technology education at the primary level except for those related to familiarity with technological equipment and internal-combustion engines. Computers are not yet used to a large extent in technology education, but use is expected to increase rather dramatically in the near future. There is evidence of substantial cooperation between teachers and industry. The biggest obstacle for the development of technology education is inadequate financial resources and the resultant lack of materials and equipment necessary to teach it.

The age, education, and work experience of the teacher and the school location did not seem to be related to technology education practice. The traditional goals of Finnish technology education and the general goals of primary education are clearly manifested in technology education. The practical aspects of technological literacy were considered to be essential aspects of technology education. The design-based teaching method is more commonly used than the more antiquated and less educationally sound copying-based teaching method. It appears as though most of the teachers in primary schools understand the concept of technology from a perspective that encompasses more than just new technological artifacts or computers. The definitions of the term technology, in fact, seemed to match Mitcham's (1994) modes of technology. The study showed that the teachers felt that technology education should include more modern technological content while, at the same time, retaining traditional educational handwork.

Wood as an educational material has over 130 years of history in Finnish technology education, and it is still an appropriate material for design-based work. Teaching resources in school, for example, support the use of wood as a construction material. Significant learning experiences in technology, such as inventing or design, do not always require complicated tasks. The cognitive and affective processes that the activities of technology education evoke are more important than what the appearance of the products produced. However, it appears that a shift is needed toward activities through which students solve real-world, technological problems. Moreover, the development of technological literacy requires experiences that are representative of all fields of technology, not just the physical elements.

A surprising result of this study was that familiarity with technological equipment was not considered very suitable for technology education at the primary school. Although the teaching of abstract and rapidly changing technical facts is not advisable, some technological concepts, principles, and their consequences and impact on nature and society can be learned through such activities. For example, as students design and make electronic or electro-mechanical equipment, the teacher could easily organize class discussion that would cause pupils to reflect upon how their work relates to society and the environment.

It was surprising to find that neither the age of the teacher nor the geographic location of the school seemed to make a difference in technology education. The respondents were optimistic about the further development of technology education in the future. This was encouraging since the teachers are the principal determinants of the curriculum. The teachers clearly felt that more financial resources were needed in order for the programs to improve. In other words, they were willing to change if the resources are available. Yet the lack of necessary resources seems to be a problem shared with technology education in most other countries. Technology education is universally one of the most expensive school subjects. Efforts to change the values of financial decision makers must continue, along with the efforts by teachers to convincingly demonstrate the values of the program relative to the cost.

One way to diversify technology education is to develop activities that correspond more closely with the modern technological world. The designing and making of products should include more theoretical elements, abstract thinking, and links to the technology that students encounter in their everyday lives. Pupils, as current and future consumers of technological products, should be able to make valid inferences about the impact of technological products and solutions on their lives. Pedagogically, more attention must be placed on developing activities that are suitable for a particular grade level.

On the other hand, the aim in developing technology education in primary schools is not to create a technology education classroom wherein pupils only read textbooks, watch videos, use computer software, and complete worksheets. The cultural, economic, natural, and social aspects, together with the technological aspects, should be considered in connection with designing and making products. Chemical and biotechnology could also be taught in conjunction with science, although they can also be taught in connection with design and making processes. The history of technology could be correlated to humanities classes as well. In summary, the objects designed and made in technology education should not be “museum artifacts,” but rather ones that are relevant to modern society. An example of such a project might be an electronic device found in some modern consumer product. In designing and making products, pupils should be taught to reflect upon the impact and consequences of technology to the society and the environment around them.

As the study indicates, teachers would be ready to include more technological content in their teaching if they had more financial resources and teaching ideas. However, they also want to preserve the traditional design and making of products, which enjoys a long, successful history in Finnish technology education. Hence, we must not throw "the baby away with the bath water" when making decisions about technology education. More than just technological understanding is needed in the future. Although technological thinking depends on specific knowledge, many examples of powerful and productive thinking result from sharing across disciplines and situations (see Bruer, 1994; Resnick, 1987). Therefore, a multidisciplinary approach like that suggested by Petrina (1998) seems most appropriate to the development of technology education in primary education in Finland. Nevertheless, more research and many more proven examples of practice are needed to accomplish these ideals.

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Identification of Quality Characteristics for Technology Education Programs: A North Carolina Case Study

Aaron C. Clark and Robert E. Wenig

Since its beginning, technology education has consistently pursued quality outcomes in course offerings. Especially during the past 25 years, the process of establishing standards, or outcomes, has been a major area of focus at both the national and state levels (Dugger, 1988). After interviewing North Carolina State Department of Public Instruction state officials, it was found that North Carolina had not identified indicators of quality that could be used to assess whether technology education programs throughout the state are meeting statewide curriculum goals and objectives. The identification of such quality indicators and the development of a correlated check sheet was the purpose of this study.

Program quality has been a concern for practitioners within technology education. However, what constitutes the elements of quality has not been adequately investigated. For example, Henak (1992) declared that quality learning in a technology education program comes from the content, learning process, experiences, and growth opportunities offered to students.

The problem of educational quality and its assessment extends to the whole of education. According to the Education Commission of the States (1992), even though there have been many attempts to develop educational standards, new information on assessing the quality of education provided in schools, districts, and states is lacking. The Federal Coordinating Council of Science, Engineering, and Technology (1993) added that an evaluation process is needed in each state to analyze programs so that questions about the quality of a program can be answered. Further, if responsible change efforts are to be made to establish quality in a technology curriculum, they must include a structure for an objective and critical assessment of each program in order to establish benchmarks for the process (Dyrenfurth, Custer, Loepp, Barnes, Iley, & Boyt, 1993). Many states in addition to North Carolina are working towards setting criteria for assessing quality within technology programs. If a state is to grow

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and develop better course offerings within its technology education programs, more research is needed. Professionals in technology education throughout North Carolina felt that a benchmarking process was needed and it should be directly linked to an assessment strategy. Secondarily, the results of this study would also be used in establishing criteria for North Carolina's "Governor's Quality Leadership Award" in education, a goal for all educational programs within the state.

Research Methodology

The Delphi technique for achieving consensus among experts was determined to be the best research method for the stated purpose of this study. Volk (1993) used the Delphi method for acquiring consensus on technology education curriculum development and Dalkey (1972) suggested the Delphi technique as a means for decision-making through the use of expert judgement. Procedures used for conducting this particular Delphi study were developed from experts on the methodology (e.g., Delbecq, Van de Ven, & Gustafson, 1986; Linstone & Turoff, 1975; Meyer & Booker, 1990). From the literature, it was determined that a four round Delphi process would be used.

The members of the panel of experts were selected by soliciting recommendations from administrators responsible for technology education, technology teacher educators, and personnel from the North Carolina State Department of Public Instruction. Individuals with the highest number of recommendations were selected to serve on the panel of experts. The resultant panel totaled 19 and consisted of 15 technology teachers, three vocational directors, and one technology teacher educator. This number was proportional to the total number of individuals within the state who serve in these respective positions.

Next, a review panel of three members was randomly selected from a list of those not selected to be on the panel of experts. The purpose of the review panel was to review and approve each instrument used in the study. This was done to reduce bias that might occur as a result of modifications made between rounds (Linstone & Turoff, 1975; Meyer & Booker, 1990). The format for the initial instrument was developed by reviewing examples from other Delphi studies (Meyer & Booker, 1990; Volk, 1993). The categories and quality indicators were identified principally from a list of similar items developed by the Maryland State Department of Education (1995).

Findings

Table 1 is a descriptive summary of the panel members and the geographic regions they represented. The population in the state is nearly equally distributed among three telephone area codes and the respondents nearly equally represented these regions. Nearly two thirds taught at the high school level. For eight of the panel members, the baccalaureate was the highest degree held while ten held a master's degree or higher. One respondent had not earned a degree. Table 2 reports information about the education experience of the panel members. The average years of teaching experience was 11 with a range of zero to 28 years.

Table 1
Selected Demographic Characteristics of Expert Panel Members

Category	*n*	%
Professional Position		
Technology Teacher	15	78.9
Technology Teacher Educator	1	5.3
Administrator	3	15.8
Total	19	100
Principal Grade Level of Position		
Middle School Grades	6	31.6
High School Grades	12	63.1
College Level	1	5.3
Total	19	100
Level of Education		
Less than a BS/BA	1	5.3
BS/BA	8	42.1
MS/Med	9	47.3
EdD/PhD	1	5.3
Total	19	100
Geographic Region		
704 Area Code	7	36.8
910 Area Code	6	31.6
919 Area Code	6	31.6
Total	19	100

Table 2
Years of Teaching Experience of Expert Panel Members (n=19)

Category	*M*	*SD*	Minimum	Maximum
Teaching experience in years	11	9.13	0	28
Administration experience in years	.57	1.53	0	6

The initial instrument, once approved by the three-member review panel, was sent to the expert panel members. This represented Round One of the study. Panel members were allowed to edit the indicators and categories and add new ones. Those that were accepted by the majority of the panel members were retained. Similar items were combined and redundant items were eliminated. Once approved by the review panel, the resulting instrument consisted of 47 indicators of quality for technology education programs across eight categories.

Round two of the Delphi process involved having the panel of experts rate the quality indicators and categories identified in Round One. The process described by Meyer and Booker (1990) was followed. This involved the use of a Likert-type scale ranging from one to five. A value of one represented a very poor indicator of quality, not considered appropriate for any technology education program. A rating of two represented a poor indicator of quality, one that 49% or fewer of the programs should meet. A value of three represented a fair indicator of quality, one that was appropriate for 51 percent or more for technology education programs within the state. A rating of four represented a good indicator of quality, one that 75 percent or more technology education programs should meet. Five represented an excellent indicator of quality, one that all technology education programs in the state should meet.

Table 3
Examples of Modifications Made to Indicators from Round Two of the Delphi Study

Indicator from Round Two	Modifications to Indicator for Round Three
The philosophy and program objectives address the need to teach the application of technology for the present and future needs of society	The program objectives address the need to teach the application of technology for the present and future needs of society
The philosophy and mission statements address the relationship among humans, society and technology	The philosophy, program objectives and mission statement address the relationships among humans, society and technology
The philosophy addresses the need to continually update and revise the curriculum	The philosophy and program objectives address the need to continually update and revise the curriculum

Using standard Delphi procedures, a mean cutoff value of 3.01 was used on the Likert-type scale responses. Quality indicators with a mean value of 3.01 or above were retained for Round Three and the others were discarded. It was thereby determined that the remaining indicators were appropriate for 51 percent or more of technology education programs within the state. All the categories were retained.

A One Factor Repeated Measures Analysis of Variance (ANOVA) was used to determine if one particular category was dominant over other categories according to a procedure suggested by Agresti & Finalay (1986). No significant differences were found among the categories. These data are shown in Table 4.

In Round Three of the study, the panel of experts were asked to rank order the quality indicators within each of the eight categories (Meyer & Booker, 1990). Sixteen of the original 19 members of the expert panel responded to this round within the established time period. No new quality indicators were suggested in this round but they did suggest six modifications. As with previous rounds, these suggestions were approved by the review panel.

Table 4
One-Factor Repeated Measures ANOVA Test on Category Names from Round Two

Category Name	*M*	*SD*	*F* value	*p*
Philosophy and Mission	4.26	.57	--	--
Instructional Program	4.21	.56	--	--
Student Populations	4.29	.63	--	--
Program Requirements	4.09	.69	--	--
Safety and Health	4.11	.65	--	--
Professional Development	4.42	.61	--	--
Facilities/Equipment/Materials	4.35	.70	--	--
Public Relations	4.25	.76	--	--
OVERALL			1.42	.20

A series of Spearman correlation coefficients was calculated between the ratings of the quality indicators from Round Two compared to rankings determined in Round Three (Gibbon 1976). This statistical process was designed to reveal the relationship between each category and its corresponding indicators. The indicators in Round Two ranged from 1 (low) to 5 (high) while the rankings within each category went in the opposite direction (1 being the highest rank). Thus, a high negative correlation was an indicator of consensus between the two rounds.

The Facilities/ Equipment/Materials Category had a low negative correlation coefficient of minus .18 and the Public Relations category had a positive correlation coefficient of plus .44. These two categories, with their indicators, did not indicate consensus. However, the overall scores combined together had a moderate negative correlation coefficient of minus .40. This suggested that consensus was being achieved between rounds two and three overall. Suggested modifications from both panels were made to indicators from this round and incorporated into the fourth and final round. These data are shown in column two of Table 5.

The Spearman's correlation coefficient was also calculated between the ranks and medians for Round Three. A positive high correlation would show that no outliers (effects of one or more extreme scores) were influencing the consensus reaching process for the indicators in this round. Such high positive correlations were found for all of the categories. These data are shown in column three of Table 5.

In the end, indicators that ranked in the upper 50 percent for a category were retained and the others were discarded. This reduced the indicators to a useable number and retained only those most likely to reach consensus in the final round.

Delphi Round Four, the final round, was intended to gain the final approval of the quality indicators from the panel of experts. All but two of the panel members responded by the specified date. Each panel member was asked to indicate whether they accepted or rejected each of the quality indicators that resulted from Round Three. No suggestions for changes to the items were permitted. Once these data were collected, the indicators were placed in a contingency table. A Chi-Square test (p<.05) was conducted to determine the quality indicators for which the panel members had reached consensus. Only one indicator did not reach the consensus criterion. That indicator required that the technology teachers and/or a vocational director prepare a written plan for a comprehensive safety and health program. It was felt by the panel of experts that this was a practice that all technology education programs must do for legal reasons and was therefore not an indicator of quality. The remaining 25 indicators, shown in Table 6, constituted the final list.

Table 5
Spearman's Rho Correlation Coefficient between Round Two Rating and Round Three Rank (Round Two), and Round Three Rank and Median

Category	*r* (*M* rate/*M* rank)	*r* (*M* rank/Mdn)
Philosophy and Mission of Program	-.90	.91
Instructional Program	-.88	.98
Student Populations	-.97	1.00
Program Requirements	-.44	.93
Safety and Health	-.82	.97
Professional Development	-.63	.95
Facilities/Equipment/Materials	-.18	.99
Public Relations	.44	.97
Overall Total Scores for Combined Categories	-.40	.95

Table 6
Final Listing of Quality Indicators for Technology Education Programs

Philosophy and Mission of Program Category:
- The program objectives address the need to teach the application of technology for the present and future needs of society.
- The philosophy and program objectives include teaching students the importance of using knowledge, materials, tools, and machines to solve problems by producing products.
- Technology teachers are actively involved in developing the philosophical and/or mission statement for the program.
- The philosophy and program objectives address the need to continually update and revise the curriculum.

Instructional Program Category:
- Course content is developed from course competencies/enabling objectives and utilizes approved curriculum guides, courses of study and professional resources.
- Course content is allowed to develop and to experiment with new technologies and areas.
- Course content is affected by the perpetual evolution of technology and society's interaction with that technology.

Table 6 (cont.)
Final Listing of Quality Indicators for Technology Education Programs

Student Populations Category:
- Technology education activities are provided for all students without bias toward gender, ethnic background, achievement, handicap, or dis-advantagement.
- All students are provided guidance about technology education course offerings at their school.
- All population types are represented in the technology education program.
- Program Requirements Category:
- Sufficient funds are budgeted for equipment and facility improvements to accomplish course objectives.
- Administration presents the attitude necessary for growth and development of technology education programs.
- The maximum number of students per period is appropriate for class population (special populations, etc.) and appropriate for the type and kind of instructional activity(ies) conducted.
- Administration is knowledgeable of the need to continually update the technology curriculum.

Safety and Health Category:
- Technology teachers prepare and teach appropriate lessons on safety.
- Students participating in technology education classes are required to complete a written safety test on applicable equipment with 100% success.
- Professional Development Category:
- The technology teacher is provided adequate time and finances to attend at least one state sponsored workshop or function.
- Adequate funding is provided for technology teachers to participate in local, state, and national professional development according to local policy and procedures.
- The technology teacher participates in staff development activities that lead to the correlation of technology education with other related academic and vocational disciplines.

Facilities/Equipment/Materials Category:
- The technology presented is applicable to the present and future workplace.
- The appearance and arrangement of the laboratory reflect the mission and philosophy of the program.
- The technology offered in the program is up-to-date with current technological needs.
- Public Relations Category:
- Teachers and students maintain a high state of visibility through the promotion of class and student activities as a public relations strategy.
- Students promote and support technology education programs through involvement in activities, including North Carolina Technology Student Association or Career Exploration Clubs of North Carolina.
- Business and industry actively communicate with the local schools.

Conclusion

Using the Delphi technique, a panel of experts within the state of North Carolina reached consensus on 25 quality indicators for technology education. Three major conclusions were drawn from the information collected from this study. First, the quality indicators listed in the findings for this study were developed for technology education programs in North Carolina, but most could be used for other programs that utilize laboratory instruction. The researchers for this study feel that since expert panel members were asked to write indicators general to all technology programs within the state that each indicator could easily be articulated into other program areas related to industrial or vocational education.

Second, the final listing of quality indicators are similar to those listed in Maryland's (1995) list of quality indicators. The 25 indicators found within this study cover the same topic areas as indicated within the Maryland listing of quality indicators. Major differences between the two lists are as follows. First, Maryland has developed hundreds of indicators and most are directly related to specific content in technology education. Maryland used a team of technology education professionals to assess program quality for schools within the state. Indicators found within this study are fewer in number and not as specific in curriculum content areas. Also, these indicators were written for school administrators with little or no background in technology education to use for program assessment.

Finally, major categories found within the study directly mirror eight of the ten categories for standards used in previous standards projects (Dugger, 1985). The researchers for this study did not pursue why expert panel members did not include categories for evaluation process and support systems. Also, the study with all categories and indicators solicited from the experts directly reflect those major areas and findings associated with the Technology for all Americans Project (1995). This reflection illustrates to the researchers that the establishment of standards and the development of quality indicators can coincide with each other and therefore, one can identify quality characteristics for programs through the establishment of standards for that same program. This process of combining the two areas together will allow technology education professionals to establish needed benchmarks for programs as we teach our students to learn to live in a technical world.

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Elementary Children's Conceptions of Structural Stability: A Three Year Study

Brenda J. Gustafson, Patricia M. Rowell & Dawn P. Rose

Background to the Study

The research reported in this paper is drawn from a much larger three-year study focused on the 1996 implementation of *Problem Solving Through Technology* topics in Alberta, Canada elementary science classrooms. In this three year study, we worked to characterize children's development of technological knowledge and skills during design technology problem solving activities and report on support needed by teachers to present these topics in classrooms. We also examined the *Problem Solving Through Technology* inquiry model presented in the *Alberta Elementary Science Program* (1996) and explored whether this model resembled how professionals (e.g., engineers) engaged in technological problem solving described their work.

The study commenced in September 1995, one year prior to the mandated implementation of a new *Alberta Elementary Science Program* (1996). In this preliminary year (Study Year One), 20 engineers were interviewed about their perceptions of technological problem solving (Rowell, Gustafson & Guilbert, 1997). One hundred fifty three children (80 male, 73 female) completed a performance based assessment related to the impending program. Three hundred thirty four children (180 male, 154 female) completed an *Awareness of Technology Survey*. Data from Study Year One provided insight into children's technological knowledge and problem solving skills prior to formal classroom instruction and information about how engineers characterized their work. In Study Year Two, six case studies were conducted on the classroom implementation of the *Problem Solving Through Technology* topics. These case studies allowed insight into the practical problems encountered by teachers and their concerns about support needed to teach design technology in an effective manner (Rowell & Gustafson, 1998). Case studies also provided a context in which we could begin to characterize how children solved design technology problems in classrooms. Study Year Three involved locating children from Study Year One and re-administering the performance based assessment and a

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revised version of the *Awareness of Technology Survey*. These data showed children's knowledge and skill development after participating in formal classroom instruction in the *Problem Solving Through Technology* topics and allowed for comparisons to Study Year One data.

In the research reported in this paper, we focus on one question from the *Awareness of Technology Survey* which was administered in Study Year One with a revised version of the question presented in Study Year Three. The question, named 'Jane's Tower,' was designed to explore children's awareness of elements which contribute to the stability of a structure. Analysis of the children's responses to this survey question allow discussion of the following two research questions:

1. How do children's perceptions of structural stability change over time?
2. Did the children offer more elegant, quality solutions in Study Year Three?

Elegant solutions were those in which the child offered one simple, useful idea which would allow the tower to be stable. Later in this study, a more thorough definition of elegance is offered and in order to address this question, data were analyzed further with attention paid to children's tendencies to provide a selective or unselective answer.

Related Literature

In recent years, there has been a growing trend towards including design technology in school programs (Layton, 1993). Arguments presented to support this trend include cultural, educational, economic, and political reasons centered on the necessity to develop children's technological capabilities and prepare them to participate in technology-related decision-making. Research on school technology programs has included analysis of the relationship between science and technology (Gardner, Penna, & Brass, 1990 ; Layton, 1993), an exploration of the dimensions of technology (Custer, 1995; Pacey, 1983), an outline of problem solving models (Johnsey, 1995), studies of classroom experiences (Davidson, Murphy, Hennessy, & McCormick 1996; Kimbell, Stables, & Green, 1996; McCormick, Murphy, Hennessy, & Davidson, 1996; Northing, 1989; Roden, 1997), and discussion of the pedagogical implications of design technology (Anning, 1994, 1997; Davies, 1996; Kimbell, Stables, & Green, 1996; Williams & Jinks, 1985).

Implicit within design technology programs is the assumption that children are in need of formal classroom experiences in order to negotiate technology problems and arrive at potential solutions to those problems. Programs, therefore, tend to include information about skills and knowledge that are believed to support technological activity (Alberta Education, 1996; Department of Education and Science, 1985; National Research Council, 1996). In school programs, technological skills such as determining needs, evaluating, planning, and making are frequently arranged into problem solving models which seek to characterize how people solve technological problems (Johnsey, 1995; Layton, 1993). Conceptual knowledge which underpins technological problem solving activities usually appears as concepts, attainment statements, content standards, or knowledge which teachers should assist children to grow towards understanding (Alberta Education, 1996; National Research Council, 1996; Tickle, 1990). Program developers maintain that through developing knowledge and skills, children will become more technologically capable (Kimbell, Stables, & Green, 1996; Layton, 1993).

Much design technology research has focused on characterizing procedural knowledge (skills involved in knowing how to do it) and organizing this knowledge into problem solving models (Johnsey, 1995, 1997; Layton, 1993; McCormick, 1996; McCormick, Hennessy, & Murphy, 1993; McCormick, Murphy, & Hennessy, 1994; Roden, 1997). Researchers have argued that procedural knowledge underpins technological problem solving, might well be context dependent, and is used in combination with conceptual knowledge (understanding relationships among relevant concepts) and strategic knowledge (planning what to do next) to resolve dilemmas which arise during practice (Levinson, Murphy & McCormick, 1997; McCormick, 1996).

It appears that less research has focused on children's conceptual knowledge of design technology (Bennett, 1996; Coenen-Van Den Bergh, 1987; Levinson, Murphy, & McCormick, 1997). This situation is in contrast to science education research which includes an impressive volume of literature on children's conceptual knowledge of science topics and the implications this knowledge has for teaching science (Driver, Guesne, & Tiberghien, 1985; Griffiths, 1994; Osborne & Freyberg, 1985).

This study is based on the assumption that research on children's conceptual knowledge of design technology has implications for curricula and pedagogy. In particular, we explore children's conceptual knowledge of elements that contribute to structural stability. Structural stability, of course, is only one concept which contributes to the production of a purposeful product. Other concepts such as those related to structural strength, joint reinforcement, and material selection represent some areas for future research. Structural stability is frequently associated with designs which include attention to symmetry, a lower center of gravity, an even distribution of weight over base, a stable base, a base broader than the top of the structure, or sinking supports into the ground (Salvadori, 1990). Related to stability are ideas about structural strength, which could contribute to stability. These ideas could include strengthening supports to prevent buckling and reinforcing joints to deter separation. Understanding the nature of children's ideas about structural stability and how these ideas may or may not be influenced through participation in school programs would be useful for both teachers and program developers.

As children use conceptual and other knowledge to solve design technology problems, they should also be encouraged to achieve quality solutions (NAAIDT, 1994). Quality solutions "are effective, efficient and acceptable solutions to perceived needs" which "achieve their purpose with minimum waste of material and energy" (NAAIDT, 1994, p. 54). Such solutions could also be termed elegant or refined and are based on the child's ability to access appropriate knowledge structures, make discerning decisions, and apply ideas. Knowledge needed to achieve quality solutions could, in part, be promoted through practice in which children continuously extend their knowledge and skills in a variety of contexts. In this study, we not only describe the children's conceptual knowledge of structural stability, but also comment on whether children were able to use this knowledge in a discerning, elegant way.

Study Framework

In order to set the context for the research reported in this paper, we begin with a brief description of the Alberta program and then provide information about study instrumentation and data collection.

Alberta Program

In September 1996, a new *Alberta Elementary Science Program* (1996) was mandated for use in Alberta schools. One feature of this program was the inclusion of a *Problem Solving Through Technology* topic at each of the six grade levels. These topics were intended to provide a context in which children could develop technological problem solving capabilities and develop a conceptual understanding of the function and structure of an assortment of devices and structures. Within the revised program, children were asked to design and make structures, boats, aircraft, other vehicles that move, and mechanisms that use electricity.

In Grade One, children participate in a *Building Things* topic that allows them to build models of structures such as buildings, furniture, toys, water wheels and boats. These experiences provide opportunities to explore methods of fastening, joining and shaping materials and the role these methods play in structural stability. Grade Two focuses on the *Buoyancy and Boats* topic in which children are expected to "modify watercraft to increase its stability in water" (Alberta Education, 1996, p. B8), an idea which emphasizes the connection between stability and shape. *Building With a Variety of Materials* is the topic presented in Grade Three in which children construct structures which support objects, span gaps, and serve as containers or buildings. Once again the children practice building techniques which can assist them to understand the link between stability and overall shape and it is likely the children also explore how stability is connected to a stable base, symmetry and weight distribution. Grade Four features a topic entitled *Building Devices and Vehicles That Move*; a topic in which children build stable vehicles through constructing a symmetrical chassis and thinking about the distribution and positioning of weight over that chassis. In Grade Five, children participate in a *Mechanisms Using Electricity* topic in which they design and construct electrical devices such as electrical cars, fans, hoists, and burglar alarms. Some of these building projects would include concepts related to stability. Grade Six features a *Flight* topic in which children build gliders, parachutes, and rockets. These projects help children understand that stability is related to overall shape and weight distribution.

The issue of developing quality solutions for technology problems is also supported in the *Alberta Elementary Science Program* (1996). Children in Grade Three must "understand that simple designs are often as effective as more complex ones, as well as being easier and cheaper to build" (Alberta Education, 1996, p. B14). In Grade Four, a list of product evaluation criteria helps students to develop decision making skills that would support more elegant, refined solutions. These criteria are repeated in Grades Five and Six and most likely would not be excluded from the more modest product evaluation performed in younger grades.

Study Method

Instrument

The instrument used was named the *Awareness of Technology Survey* and featured a selection of questions intended to explore children's ideas about concepts and skills related to the *Alberta Elementary Science Program* (1996). Each of the six grade levels had a different selection of survey questions with some questions being repeated at each grade level if they were judged related to the entire program (e.g., the question about structural stability).

Awareness of Technology Survey questions were either created by the authors or patterned after survey questions posed by a number of other writers (Aikenhead, 1988, Coenen Van Den Bergh, 1987; DES, 1992; Gadd & Morton, 1992 a,b; Harrison & Ryan, 1990; Rennie, 1987; Rennie, Treagust, & Kinnear, 1992; Symington, 1987). Consultations with provincial government personnel familiar with the new elementary science program who had additional experience with developing test items for provincial science achievement exams were used to validate survey items with respect to the new program.

Piloting

Sections of the *Awareness of Technology Survey* were piloted with a group of 140 children in grades one through six (ages 5-12). Grade One children who had yet to develop adequate reading skills had questions read to them as a group; this approach was used despite the fact that the Grade One survey contained little writing. Children's oral questions and advice as well as teacher comments were noted. Written survey responses were analyzed to check whether they addressed the original intent of the questions and, subsequently, revisions were made to wording and format. From this piloting experience, the *Awareness of Technology Survey* was constructed which was used in Study Year One. A revised version of this same survey that asked children to elaborate more on their answers 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 close to a large urban area. Classrooms were selected by the school system's Program Facilitator who worked 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. Children in other grades who still might be experiencing reading difficulties were encouraged to ask their teachers for reading assistance

In Study Year Three, 190 children (93 male; 97 female) were located who had participated in Study Year One and a revised version of the *Awareness of Technology Survey* was administered to them. Excluded from Study Year Three data collection were those students who had been enrolled in Grade 6 in Study Year One. Grade 6 students from Study Year One were excluded because in Study Year Two they would have been in Grade Seven (Junior High School) and therefore, would not have participated in classroom experiences related to the design technology topics which were part of the *Alberta Elementary Science Program* (1996). As one of the intentions of re-administering the survey in Study Year Three was to provide feedback on how children's ideas might have changed due to classroom experiences with the design technology topics, it was not useful to include these children.

Study Focus

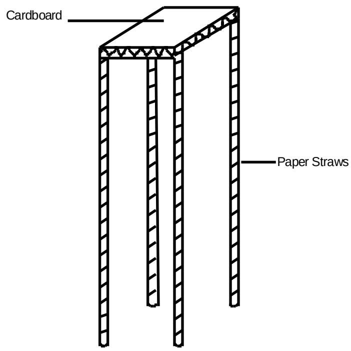
This study will focus on one *Awareness of Technology Survey* question which was administered in Study Year One with a revised version presented in Study Year Three. The question, named 'Jane's Tower,' was designed to explore children's awareness of elements which contribute towards the stability of a structure (see Figures 1 and 2). Results from Study Year One were reported previously (Gustafson & Rowell, 1997, 1998), and attention was drawn to the difficulties experienced by children enrolled in Division I classrooms (Grades 1, 2 and 3) as they tried to provide solutions for the survey question. Children in Division II (Grades 4, 5 and 6) experienced far less difficulty. Therefore, in this study, we focus on 121 children (59 male; 62 female) who were in grades one, two, and three, during Study Year One, who participated in classroom experiences that included exploring structural stability during Study Year Two, and who were in grades three, four, and five during Study Year Three.

Data Analysis

Data analysis began with researchers reading through children's survey responses and collaboratively compiling lists of ideas about structural stability that the children used to answer the question. The complicated and sometimes surprising nature of the children's responses in Study Year One made it necessary to spend considerable time designing and revising these lists, which were subsequently reorganized into coding sheets. Broad categories of 'Ideas Likely to be Useful' and 'Ideas Unlikely to be Useful' were subdivided into the specific ideas offered by the children. Upon generation of coding sheets, a sub-group of randomly selected surveys was independently analyzed by each study researcher, and these were compared to establish reliability among coders.

A single survey response could contain a number of suggestions to prevent Jane's Tower from tipping. For example, one child suggested that a base could be added to the tower (a useful idea), the straw supports could be sunk into the holes drilled in the base (a useful idea), and the base could be made of a heavy material such as wood or metal (a useful idea). This response would fall into three coding categories. Additionally, it would be judged overall as a design which would likely increase the stability of the tower. Other survey responses contained a combination of useful and unlikely to be useful ideas. This type of response could also fall into several coding categories and could be judged as likely or unlikely to be stable overall.

JANE BUILT THIS TOWER USING PAPER STRAWS AND CARDBOARD.



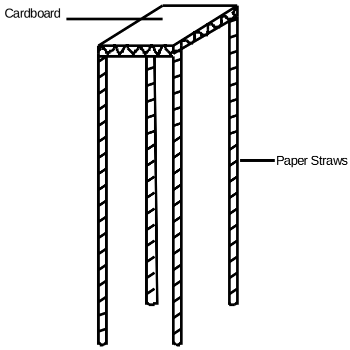
SHE FOUND, HOWEVER, THAT HER TOWER WOULD TIP OVER VERY EASILY. DRAW A PICTURE OF HOW YOU WOULD CHANGE JANE'S TOWER SO THAT IT WOULD NOT TIP OVER. LABEL YOUR PICTURE.

MY TOWER

I CHANGED JANE'S TOWER BY ______________________
____
____
____
____
____

Figure 1. Jane's Tower Survey Question—Study Year One.

JANE BUILT THIS TOWER USING PAPER STRAWS AND CARDBOARD.



SHE FOUND, HOWEVER, THAT HER TOWER WOULD TIP OVER VERY EASILY.

DRAW A PICTURE OF HOW YOU WOULD CHANGE JANE'S TOWER SO THAT IT WOULD NOT TIP OVER. LABEL YOUR PICTURE.

MY TOWER

I CHANGED JANE'S TOWER BY ___________________________________
____
____.

MY TOWER WILL NOT TIP OVER BECAUSE _______________________
____
____.

WHERE DID YOU GET THESE IDEAS ABOUT TIPPING OVER?
____
____
____.

Figure 2. Jane's Tower Survey Question—Study Year Three.

Results

Children's Perceptions of Structural Stability

Prior to formal classroom instruction about structural stability, children at all three grade levels drew and wrote about an impressive array of useful ideas which could increase the stability of Jane's Tower (Gustafson & Rowell, 1997, 1998). Many of these same ideas were repeated in Study Year Three (see Table 1).

The first section of Table 1 shows that some children believed that the addition of a base to Jane's Tower could potentially play a role in stabilizing the tower. Children believed that a stable base could be achieved through adding bases of different sizes and weights; ideas which could contribute towards lowering the center of gravity. Other children added 'feet' to the bottom of the supports that, in effect, broadened the base of the tower. A small number of children suggested sinking the supports into the ground or joining the supports to the desk which resulted in the ground or desk becoming a kind of base.

Ideas related to modifying the supports seemed of particular interest to many of the children. Adding extra straw supports or thickening existing supports could enhance stability while shortening the straw supports would help lower the center of gravity. Some children were concerned with bracing the supports through the addition of internal cross or square bracing or external bracing such as guy lines. Other children were concerned that the supports were made of paper straws; a material they deemed to have insufficient strength to provide adequate stability. These children changed the straw supports to a more substantial material like wood, metal, concrete, cardboard, and brick. We judged these materials to be heavier than paper straws and because of their potential to lower center of gravity they were seen as potentially useful ideas.

Some children suggested modifications to the platform and these ideas could be judged useful or not useful depending on the combination of ideas offered in the survey response. For example, some children widened the platform or changed the platform to a heavier material such as wood, metal, concrete and brick. These heavier materials could enhance stability by creating a downward stabilizing force. To be considered positively, however, this suggestion had to offered in conjunction with suggestions about how supports should be modified to sustain this additional weight. Children who simply suggested a brick platform supported by paper straws were judged to have offered an idea about platform modification which was not useful.

Some children in all grades suggested that existing and new joints could be reinforced with nails, glue, tape, clay, screws or cement. These ideas were judged useful because preventing joints from buckling or giving way could contribute to stability. Other children offered the idea of simply changing the material from which the structure was made to wood, metal, concrete, cardboard, or bricks. This suggestion was judged useful since these heavier materials could increase stability.

Table 1
Children's Ideas About Structural Stability: Study Years One (SY1) and Three (SY3) Comparison

Ideas about Stability	Grade 1 in SY1 (*n*=54)	Grade 3 in SY3 (*n*=54)	Grade 2 in SY1 (*n*=25)	Grade 4 in SY3 (*n*=25)	Grade 3 in SY1 (*n*=42)	Grade 5 in SY3 (*n*=42)
Base addition	3	0	5	2	6	4
Base wider than top	2	8	2	5	7	8
Sinking structure into ground	3	0	0	0	1	0
Joining supports to desk	0	2	1	0	1	1
Adding extra supports	5	5	2	1	4	9
Shortening the supports	4	5	0	2	1	7
Thickening the supports	4	5	0	1	0	1
Bracing the supports (internal)	5	1	6	12	6	10
Bracing the supports (external)	2	4	4	2	6	4
Splaying the supports	2	0	0	1	1	3
Changing support materials	15	13	8	7	18	9
Widening the platform	7	2	1	6	2	3
Changing platform to another material	6	7	4	5	7	1

Table 1 (cont.)
Children's Ideas About Structural Stability: Study Years One (SY1) and Three (SY3) Comparison

Ideas about Stability	Grade 1 in SY1 (*n*=54)	Grade 3 in SY3 (*n*=54)	Grade 2 in SY1 (*n*=25)	Grade 4 in SY3 (*n*=25)	Grade 3 in SY1 (*n*=42)	Grade 5 in SY3 (*n*=42)
Joint reinforcing	3	5	5	0	7	8
Modified entire tower to another material	7	18	1	0	2	3
Not useful ideas	18	6	2	2	5	0

Other design suggestions were judged unlikely to be useful. These ideas tended to be suggested by children in Grade One in Study Year One. They included removing one or two of the supports, moving the supports towards the middle of the platform, building a bigger tower, making the platform heavier while not making modifications to support this increased weight, or simply substituting the materials with light weight plastic. Other children added decorative touches to the platform such as railings, a chimney, a roof, a rooster, cotton balls, and stairs. Some children simply changed the tower to something else (e.g., water tower, barn, silo, lighthouse, temple) making it impossible to judge the way in which they were addressing the stability problems of Jane's Tower. Table 2 shows that the ideas suggested by each child frequently led raters to conclude that Jane's Tower had, in the end, been rendered more stable.

Table 2
Proportion of Children's Towers Likely to be Stable: Study Year One (SY1) Versus Study Year Three (SY3) Comparison

Grade 1 in SY1 (*n*=54)	Grade 3 in SY3 (*n*=54)	Grade 2 in SY1 (*n*=25)	Grade 4 in SY3 (*n*=25)	Grade 3 in SY1 (*n*=42)	Grade 5 in SY3 (*n*=42)
89%	96%	96%	96%	100%	100%

Children's Ability to Achieve Elegant Solutions

Children who achieved a stable tower might have suggested a combination of useful and unlikely to be useful ideas. However, the data show that, in the end, children would quite likely have achieved a stable tower that was judged to be an overall success. An important objective of design technology is to achieve solutions which are "elegant" in nature. A definition of an elegant solution is one in which costs are controlled, time limits are met, criteria are fulfilled, and a solution is reached that is marked by its precision and simplicity (Rowell, Gustafson, & Guilbert, 1997). For Jane's Tower, it would be difficult to judge whether cost and time limits were met. Thus, an alternative definition of an elegant solution for this study was one in which the child offered a single, simple, useful idea that would allow the tower to be stable. This useful idea would not be clouded with ideas unlikely to work or useful ideas that were simply unnecessary. An example of an elegant solution would be a child who wrote simply that the supports should be splayed. This was a solution that was based upon a single, simple idea and it was all that was needed to stabilize the tower.

In Study Year Three, children showed an overall increase in the number of elegant solutions offered (see Table 3).

Table 3
Proportion of Children with Elegant Solutions: Study Year One Versus Study Year Three Comparisons

Grade 1 in SY1 (*n*=54)	Grade 3 in SY3 (*n*=54)	Grade 2 in SY1 (*n*=25)	Grade 4 in SY3 (*n*=25)	Grade 3 in SY1 (*n*=42)	Grade 5 in SY3 (*n*=42)
24%	37%	16%	20%	24%	41%

One might wonder if the students who came up with elegant solutions in Study Year One were the same ones who had elegant solutions on Study Year Three, joined by a few more. Data analysis showed, however, that children who offered elegant solutions in Study Year One were just as likely as other children to offer inelegant solutions in Study Year Three. This observation supports the view that some children were either unable to recognize the value of the elegant solutions offered in Study Year One or had yet to sort through ideas about stability they encountered by Study Year Three.

Discussion

Children in Study Year Three tended to retain useful ideas from Study Year One and mention some of these with a greater frequency than they did in Study Year One. Ideas that were deemed to be less useful appeared with less frequency in Study Year Three. This suggests that life experiences and maturation in the intervening years may have played a role in assisting some children to notice design solutions critical to stability.

An area of interest in Study Year Three concerned the children’s suggestions about materials. Some Study Year One suggestions involved changing the platform to a heavier material while failing to strengthen supports. This combination of ideas would likely lead to the buckling of supports and collapse of the tower. This notion about making the platform out of a heavier material had the potential to be a useful idea, but for some children it was still in need of further refinement. In Study Year Three, some children continued to increase the weight of the platform while paying little attention to support. Assisting children to refine this and other ideas about materials represents a worthwhile focus for further teaching. Opportunities to explore a wide range of materials and the interplay of these materials with each other within a design problem could help children to construct an understanding of the role that context plays in promoting links between conceptual knowledge and procedural knowledge.

It is difficult to draw links between overall trends in children's thinking about useful materials in Study Year One and Study Year Three and the role classroom experiences might have played in this thinking. For example, in Study Year One children mentioned changing tower materials to concrete, metal or wire. In Study Year Three, children continued to mention concrete and metal but no longer subscribed to using wire. Despite this change, it is unlikely in the intervening year that children had any classroom experience building with these materials. Perhaps ideas about materials such as these were based on experiences and observations outside the classroom and the seemingly indiscriminate inclusion and exclusion of materials ideas in Study Year Three reflected the lack of classroom opportunity to practice discernment with a wide variety of materials.

A partial answer to the question about the source of the children's ideas was provided by the Study Year Three survey question. Approximately 21% of these children responded that they used ideas from experiences outside the school classroom to modify Jane's Tower. Opportunities to watch new homes being built in the neighborhood and view real towers standing in fields were mentioned as sources of ideas about stability. Experiences inside their homes were also important and children wrote about hearing parents (mostly their fathers) talk about stability, viewing programs about structures on television, noticing that they tended to tip over when tying shoes, viewing tipped over chairs and tables and playing with "stuff" that tips over. Personal knowledge of stability constructed from these encounters clearly influenced some responses and could help account for the range and resiliency of materials and design ideas.

Other children (about 22%) wrote that their ideas for solving Jane's Tower were derived from school experiences and they mentioned watching videos at school and participating in activities from the previous year that involved structural stability. About 24% of the children did not identify a specific past experience which helped solve the problem, but rather wrote they got their ideas "from their brains," or "from just looking at it." This particular response does not necessarily rule out the influence of school experiences but rather shows how difficult it can be to identify idea sources. Regardless, children's responses about idea sources show that classroom and personal experiences were seen as equally important sources of information about structural stability and this could help account for differences between Study Year One and Three ideas.

Table 2 shows children in all grade levels had a very good chance of achieving a solution that would enhance the stability of Jane's Tower. Each child, however, could have achieved a successful tower through using a combination of useful and not useful ideas. For example, one child who achieved a successful tower suggested six different ideas in his answer–four useful and two not useful. These kinds of answers showed that some children had overlooked distinctions between useful and not useful ideas but had fortunately struck upon some ideas that would lead to overall success. This suggested that some children met with overall success despite offering unselective solutions and that perhaps overall success might have been attained through happenstance. If this was the case, perhaps overall success rates reported in this study were not as impressive as anticipated because they could have been due to the indiscriminate use of ideas. Be that as it may, children did offer many good ideas and perhaps the issue of helping children to refine ideas and offer more elegant, quality solutions would be a laudable goal of classroom teaching.

Table 3 shows that children in all grades were capable of achieving an elegant solution that used one useful idea to make Jane's Tower more stable. In Study Year Three, there was an increase in the percentage of children who achieved elegant solutions. A second analysis of children's solutions centered on whether inelegance in Study Year One was a good predictor of inelegance in Study Year Three. Data showed Grades One and Two children who offered inelegant solutions in Study Year One were very likely to offer inelegant solutions in Study Year Three. This suggested that these young children still needed practice in recognizing effective, efficient solutions. What seemed most confusing to them was the cardboard platform. Many of these children continued to propose changing the platform material from cardboard to an alternative material while neglecting to strengthen the supports. In contrast to this were those enrolled in Grade Three in Study Year One. The children in this group who offered inelegant solutions tended to abandon their indiscriminate thinking and offer much better solutions in Study Year Three. Thus, the presence of an inelegant solution in Grade One, Study Year Three was not a good predictor of inelegance in Study Year Three.

These observations hint at the complicated nature of the thinking that contributes to achieving elegant solutions. In order to propose an elegant solution to the Jane's Tower survey question, children needed a conceptual understanding of stability (possibly informed by personal experiences), the ability to sort and order this information, and the ability to apply such knowledge to Jane's Tower and make appropriate decisions (NAAIDT, 1994). In this study, it proved challenging for some young children to negotiate this complicated terrain.

Engineers who are also faced with constructing elegant solutions to technical problems speak of working through a similar process to achieve solutions. In engineering, "solutions to problems are not found or discovered, but selectively constructed to achieve a satisfactory outcome that satisfies the often contesting criteria of the situation" (Rowell, Gustafson, & Guilbert, 1997, p. 90). Elegant solutions, therefore, tend to be the product of sustained, informed, intellectual effort that may be difficult for some young children. Assisting children to practice discernment through sharing and analyzing ideas while keeping in mind the criteria that are to be met would be a useful goal of design technology teaching.

Conclusion

This study showed that children have a variety of ideas and an understanding of the concepts of structural stability even before engagement in a formal instructional program designed to teach this material. Some of the ideas that they proposed appear to be derived from a variety of past experiences; some are useful in solving the problem and others are not. After formal classroom activities about structural stability, some children showed an increased ability to discern between useful and not useful ideas, but they did not necessarily identify classroom experiences to this gain in discernment. In order to support children's conceptual understanding of structural stability, programs should encourage teachers to explore children's personal knowledge and design activities which assist children to consider and evaluate useful and not useful ideas.

Discussion about achieving elegant solutions showed that young children require assistance to properly solve technological problems. Technological problem solving is characterized by an interplay of ideas and children need time and support to sort through ideas, make decisions about which ideas are most likely to work, and then further refine these ideas into simple, successful solutions. In order to undertake this sustained, intellectual effort, children need to construct an appreciation for the value of elegant, quality solutions. Quality solutions are supported by teachers who provide opportunities for children "to be taught to apply technological knowledge, discuss and analyze their work, justify ideas, materials, and techniques they have used and to propose modifications and improvements" (NAAIDT, 1994, p. 53). Through this sustained effort, children participate in the iterative thinking or choice making which is inevitably part of technological problem solving. Through this they can learn to recognize that simple solutions are often as effective as complex ones. Productive areas for future research include exploring children's understanding of additional design technology concepts, exploring the role that children's personal knowledge plays in arriving at successful solutions, and studying the efficacy of school design technology programs.

An earlier version of this paper was presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), April 19-22, 1998, San Diego, CA. The support of this work by SSHRC-Northern Telecom Grant #812950007 is gratefully acknowledged.

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Content or Process as Approaches to Technology Curriculum: Does It Matter Come Monday Morning?

Theodore Lewis

Content, which focuses upon conceptual structure, and process, which focuses upon intellectual skills, are two preeminent ways in which technology educators conceive of curriculum (e.g., Bensen 1988). Clearly, if technology is to have validity as a school subject, its adherents must be able to say what it is uniquely about. They must be able to answer the basic question, “What do you teach?” And as the subject is taught to children, teachers must likewise be able to say to them and their parents what they will learn, different from in other classrooms. Both content and process claimants may argue, perhaps with justification, that their particular curricular approach reveals technology to students. If it is the case that these two ways of thinking are each capable of helping students acquire literacy in the subject, then perhaps there is need to view them not dichotomously, but rather symbiotically. Perhaps, then, the approach to curriculum does not really matter. Maybe it is how this all plays out in actual classrooms that counts. Still, content and process have their own particular champions, and a divergent discourse along these two distinct lines can be traced.

In what follows, these two ways of thinking about the subject are examined critically. First, the lineage of the quest for conceptual structure is traced back into the industrial arts era. Next, challenges inherent in attempting to establish technology education, in the absence of a coherent discipline structure, are discussed. How the connection between technology the school subject and technology the realm of human existence might be viewed, is explored, borrowing from the work of Stengel (1997). Process approaches and their justification are next examined and critiqued. A discussion follows in which the competing rationales, arguments, and counter-arguments are reflected upon. Whether the tensions here are of any significance come Monday morning in the typical technology education classroom or laboratory provides the basis for concluding comment.

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The Perennial Search for Conceptual Structure

The recent publication of the curriculum document *Technology for All Americans*, in which a rationale and structure for the study of technology is set forth (International Technology Education Association, 1996), is evidence that the subject matter and conceptual structure of technology education still remains an unsettled issue and a preoccupation of leaders of the field in the United States. Explaining the need for a structure for the subject, the ITEA authors asserted that technological literacy must be operationalized. The field must be able to say just what experiences, abilities, and knowledge pertaining to technology must be exhibited for one to make the literacy claim. Thus, three elements of a structure (processes, knowledge, and contexts) are proposed as universals underlying technology. Suggesting a new path for the field, content and process are shown to be inherent in its structure.

The continuing quest for clarity and specificity regarding subject matter constitutes unfinished business for the field, left over from the era of industrial arts. Very early on, industrial arts leaders at Teachers' College, Columbia University had come forward with the view that the conceptual structure of industrial arts needed to be articulated. For example, McMurry (1905) argued that "probably the most pressing need in establishing manual training more firmly is fuller evidence that the subject contains a body of thought comparable in importance to that of history, geography, or nature study" (p. 563). That way of thinking has not receded.

In his seminal work, "*A Curriculum to Reflect Technology,*" Warner (1947, 1965) suggested that content in the "new industrial arts" would be derived from socioeconomic analysis of the technology, rather than through task analysis of trades. Thus, the subject would be framed by a new schema. "Socioeconomic analysis" for Warner meant resorting to standard industrial classification rubrics. This classification yielded power, transportation, manufacturing, communication, and management, as content organizers. Warner and his students provided detailed conceptual structures for each of the content categories he proposed.

But this was not the first time that standard industrial classification had been suggested as the way to structure the field. Russell (1914) had already proposed such a schema for the subject when he suggested that "the dominant processes in the successive stages of production, manufacture and distribution, and their interrelations" (p. 11) ought to be taken into account in fashioning the subject matter.

By the mid-1960s, despite Warner's classification work, leaders of the field were still clamoring for a new structure within which to frame industrial arts content. In the theoretical work that supported the American Industry project at the University of Wisconsin-Stout, the search for structure and new content organizers was evident. In an essay titled "Industrial arts—What is its body of knowledge?" Robert Swanson (1965) pointed out that the field had traditionally adopted an eclectic approach to curriculum derivation, but that this eclecticism notwithstanding, "it seems that any subject worthy of time in the school must demonstrate that it is uniquely prepared to transmit and interpret this knowledge" (p. 58). Following Bruner (1960), he argued that structure makes the subject matter coherent and comprehensible, and that it helps clarify the subject's relationship with others in the curriculum. Where McMurry had offered *status* as the primary reason for finding structure, Swanson was now offering *cognition*.

Face, Flug, and Swanson (1965) explained the American Industry project as a quest for a structure of industrial arts. The basic elements of structure were to be *concepts*. American Industry was to be an intellectual discipline, to be structured on the basis of concepts common to a variety of industries (such as transportation, processes, and materials).

Leaders at The Ohio State University also premised their landmark work on the assumption that the subject matter of the field needed to be articulated. The basic premise of their Industrial Arts Curriculum Project (IACP) was that the content of industrial arts was nested in the higher plane of praxiology or technology (Lux & Ray, 1970; Towers, Lux, & Ray, 1966). Trying to articulate the complete structure of technology would be impractical, thus the scope would be delimited to *industrial technology*. Correspondingly, manufacturing and construction became the primary content organizers and the conceptual structure for these two areas were developed. In retrospect, this decision to structure *the subject* and not *the discipline* was eminently sensible.

In his classic monograph "Come Monday Morning," William J. Micheels (1978) offered as his anchoring premise the view that "Industrial arts education is an eclectic discipline" (p. 1). He explained that by the term "discipline" he meant simply that which was to be taught to students. Come Monday morning, the typical teacher had the option of choosing from a diverse array of sources, systems, and styles. Micheels argued further that amid the diversity of approaches and choices, there were three common denominators of the subject: tools, materials and ideas. These three common themes would hold, even if the rationale for the subject was the nature of technology and its impact on society. And they would hold even as the focus of pedagogy in the subject shifted to creativity, problem solving, and design. He explained:

> Learning how to solve such problems can be an important goal of industrial arts instruction. There should be experiences in working with many kinds of tools and materials. There should be opportunities to experiment, invent, construct, create, produce, and *think* about metals, plastics, wood, electronics, energy, power, graphics, and other materials, methods and forces which can stimulate imagination and develop creative abilities. (p. 15)

Micheels had refrained from joining others in calling for a conceptual structure. Tools, materials, and ideas were, in his view, sufficient parameters to lead to comprehensive elaboration of the subject in schools. Micheels was assuming, here, the disposition of a teacher. It was the children and what they learned that mattered, not the method of deriving content or the instructional approach that one adopted. There is much wisdom in Micheels' entreaty. We may have overdone the quest for structure, forgetting the grander purpose of schooling and the educative role of the subject.

This brief historical reflection shows that the quest for discipline status and structure has been a perennial in the field, originating early in the industrial arts era, and providing impetus for the transition to this new era of technology. Arguably, the preoccupation with discipline structure really has to do with the quest for status and power. We see this clearly in the case of accounting. Hoskin and Macve (1993) contended that the disciplinary status of accounting is central to understanding the emergence of the modern business enterprise. Once accounting had emerged from the shadows, no longer basing its legitimacy merely as a derivative of fields such as psychology and economics, what followed was the emergence of the modern business enterprise. The *disciplinary power* of accounting, combined with knowledge practices, facilitated administrative coordination. Hoskin and Macve went to lengths to trace the disciplinary metamorphosis of accounting. But they caution that the future of accounting lies not so much in it being recognized as a "pure-knowledge" discipline, but rather as "power-knowledge," that is, in terms of its indispensability to business practice.

It is useful to see that the disciplinary quest is not peculiar to the subject that we now call technology education. Attainment of disciplinary status has to be viewed as a sort of epistemological badge of honor, a sign that one's field has arrived. In the society at large, of course, technology has nothing to prove. People have been to the moon. The Internet has made the global village a reality. This power of a ubiquitous and even deterministic technology does not readily transfer to school technology however. In American schools we know that a subject has arrived when it is required, and not merely an elective, or when the universities specify it as an entry criterion. School technology is not yet there. Thus, the quest for status and power continues.

Disciplinary Status and the Validity of Subjects

The appearance of Bruner's *The Process of Education* provided a new stimulus and rationale for a conceptual structure for industrial arts in the 1960s. Bruner wrote that structure promoted discovery learning. It made learning more comprehensible, thereby promoting transfer. Thus, the reasons why structure was important were grounded in cognitive psychology. Schwab (1962) advocated structure for similar reasons. He wrote:

> The structure of a discipline consists, in part, of the body of imposed conceptions which define the investigated subject matter for that discipline and control its inquiries. (p. 199)

Structure aided inquiry. It also afforded renewal of subject matter. Facts endured, while knowledge decayed and regenerated. Each discipline had its peculiar conceptual apparatus. The body of concepts was one aspect of a discipline, the syntactical structure, focusing on the method of the discipline, was another. Schwab's positioning of conceptual structure and syntactical structure conjointly is important because it allows us to see that the method of technology—how the goals of technology are accomplished—must be integral to its discipline structure. Neither conceptual nor syntactical structure alone would be a complete conceptualization.

Curriculum leaders in industrial arts now had a mainstream rationale for their quest for the articulation of subject matter. DeVore (1969) adopted the notions of Schwab and Bruner, arguing that, “A curriculum based on organized knowledge fields is better learned and retained than knowledge which is specific and isolated” (p. 41). Reviewing extant approaches to industrial arts, he opined that the field should adopt the stance that the industrial arts curriculum should be based upon “the study of man and technology” (p. 43). His reasoning was that by claiming technology, the field “identifies a knowledge area meeting the criteria of a discipline in the truest sense of the term” (p. 43). Technology was “an area of human knowledge, as are the sciences and the humanities” (p. 42). The sphere of study would include “the modes of thinking, the problem solving and the solution of technical problems together with the socio-cultural relationships involved” (p. 42).

In drawing attention to the need for both a body of knowledge and for identification of modes of thinking, DeVore had articulated for the field how it needed to think about conceptual and syntactical structures simultaneously. Content and process went hand in hand. This is the line of thinking we now see in *Technology For All Americans*. DeVore (1970) subsequently proposed a research program designed to yield both discipline structure and process.

In this era of transition from industrial arts to technology education, the disciplinary claim has been a recurring theme in the literature (e.g., Dugger, 1988; Lewis, 1991; Lewis & Gagel, 1992). And as indicated above, the ITEA (1996) has returned to the idea of creating a rationale and structure for the study of technology.

Why Calls For Structure Have Been Problematic

In calling for conceptual structure, the first problem for the field was that the claim that technology is a realm of knowledge went against the grain of epistemological tradition. Technology did not conform to the received view of what constituted valid knowledge (see Lewis, 1993). It was not one of the forms of knowledge identified by Hirst (1975). In fact, it seemed to align more closely with what Hirst referred to as “fields,” being derived from practical interests. To be a discipline in Hirst’s schema, a subject had to have a distinguishing mark—a particular test of experience. For example, science depended on empirical tests, mathematics upon deductions. But could not technology claim its own test of experience? Such a test would be whether or not a particular tool or device or process worked (e.g., Skolimowski, 1966). If it is the case that technology does possess its own central concepts (which it must), and indeed lends itself to a peculiar test of experience, then a strong disciplinary claim could be made for it, using Hirst’s criteria. Technology’s absence from Hirst’s schema can probably be better explained in terms of a Platonic reflex. Some types of knowledge are more equal than others. Thus disciplines are superior to fields. But if we could forego the sociological problem here, Hirst’s concept of “field” does allow much possibility for the coherent organization of technological concepts and practices. Fields are imbued with a built-in elasticity that seems perfect for technology, given its dynamic nature. We should expect that knowledge in technology would decay and regenerate more rapidly than in other subject areas.

Whether discipline or field, a universally accepted knowledge structure for technology had not been articulated by the 1960s when innovative curricula were being proposed in the bid to reform industrial arts. Beyond epistemological inertia, there was the fact that much remained unsettled about the nature of technology. Was technology skill? Was it applied science? Was it like science or was it a system of thinking unique onto itself (see Bunge, 1966; Feibleman, 1966; Layton, 1974; Skolimowski, 1966)? With desperately important issues such as these still occupying the minds of scholars, and still the object of contestation, articulation of subject matter of the discipline could not properly proceed. It is true that Warner, DeVore, and the project leaders of IACP had taken it on their own to try to create the outlines of the discipline of technology. But such an undertaking, given its gravity, required at least an interdisciplinary project. Technology teacher educators simply did not have the standing in academia to take this on alone and have it validated. As a consequence much of the work on the structure of technology that has been done in the field is known only within the field and is rarely cited outside of it.

Also in the 1960s, the field of history of technology germinated, and like technology education, advocates found themselves wanting of an articulated discipline structure. For example, Ferguson (1974) observed that while the history of technology had "all of the appearances of an academic field, yet it is difficult to find in it a discipline or conceptual framework that guides the work being done in its name" (p. 13). The fledgling field of philosophy of technology also had the same need. Rapp (1989) asserted that:

> What is lacking in the philosophy of technology is precisely a well elaborated state of the art. The situation is different from other fields of philosophical inquiry. In such areas as the philosophy of history, ethics... philosophy of language or philosophy of science, there has been long standing discussion; there is a well established, systematic conceptual framework of basic concepts, questions, theses and arguments...For philosophy of technology a similarly detailed and elaborate theoretical frame of reference is mainly desideratum. The field is still in the making. (p. ix)

This is exactly what McMurry (1905) was saying about industrial arts in the first decade of this century. Thus, historians and philosophers of technology, much like technology educators, were lamenting the absence of a conceptual structure. Technology educators were not alone.

It is sobering and quite instructive that the quest for an articulated structure of technological knowledge has not impeded actual teaching of the subject in schools. The metamorphosis of technology education in American schools began in the 1880s, and while it is the case that there has been perennial search for structure, such a search has essentially been a preoccupation of advocates in the universities. But at the primary site where the subject is enacted—schools—the subject has proceeded and has evolved. The work that has gone on in schools, at the grass roots, needs to be recognized and validated, since that work is a truer reflection of what the subject is about than what campus-bound advocates might profess. The subject has proceeded as if it was oblivious to the absence of structure. In light of the seeming disconnection between the quest for discipline structure and actual school practice, we have to look again at the supposed relationship between academic disciplines and school subjects in the particular case of technology education. Does school technology have to be a mirror image of the discipline of technology?

Stengel (1997) pointed out that the relationship between school subjects and academic disciplines is complex. She sets forth a typology that, among other things, allows for the prospect that school subjects can *precede* academic disciplines. What this would mean in practice is that the curriculum is not externally controlled by subject-matter experts. In the case of technology education it means that we do not bring in the engineers, doctors, systems analysts, and agriculturists to lay down curricular tracks for technology teachers. Rather, the curriculum is dictated by the accumulated experiences of children and their teachers.

Stengel indicated that when the discipline precedes the subject, traditional academic goals and assumptions go untested, as teachers strive to create connections between disciplinary knowledge and the lives of children. This analysis is quite breath taking. As we look at technology education and the perennial, almost ritualistic quest for structure, it should be sobering that a cost of such quest might be the neglect of the needs and experiences of children. Perhaps it is because the field is highly masculinized and is consequently taken in by technological gadgetry. But especially in the U.S. context, where the subject is rarely taught in the elementary grades, focus on children and on learning is minimal in our discourse. Technology *per se* has been our consuming passion and we forget that the enterprise we are about is schooling. We take too seriously the view that without our field technology would not be purveyed. That of course would be highly presumptuous, although it is true that without the subject in the curriculum one can point to a clear epistemological void. The fact is that in societies such as the United States, where people are so immersed in technology in day-to-day life, we can assume that their functional knowledge of technology—that knowledge acquired from commonplaces—would contribute substantially to their literacy. There are means beyond schooling by which societies retain memory of their technological store. Thus, the focus of the field has to be upon the children, not the technology. If the advocates begin to think in this way, how we view curriculum will change.

One critic of the discipline quest has suggested that the field does not have a clear grasp of the nature of technological knowledge (Herschbach, 1995). According to Herschbach, technological knowledge is unlike other forms of knowledge. It is not just a storehouse of facts, laws, and theory. It is alive. It has meaning only when enacted in laboratories. Technology, he argues, “is not only content to be learned but the vehicle through which the intellectual processes embedded in technological activity can themselves be learned” (p. 39). Herschbach ties content to process. There is much in favor of this view. Others have come to view process *per se* as content, and a reason to call off the quest for structure.

From Content to Process

Though discipline structure has been a preoccupation, the process approach to technology has also had sway. While the origins of the process approach are difficult to pin down on the American scene, if we go back to the critical period of innovation in the 1960s and early 1970s, we find that Donald Maley was a strong advocate. Maley separated himself from other curriculum leaders by focusing his educational philosophy upon children rather than on content. Thus, he did not become entangled in calls for discipline structure.

Maley (1963) described a research and experimentation approach to industrial arts. The program would provide challenges for all students, including the academically gifted. It would emphasize problem solving. He explained:

> America needs people capable of problem solving, capable of making decisions, and capable of using sound procedures in arriving at decisions. Herein, the research and experimentation program has one of its greatest strengths in that the principal vehicle of the activity is the scientific approach which forms the backbone of each experiment or research problem. (p. 26)

Maley made an assumption about the existence of content, and chose to concentrate his efforts on having children experience the act of technological creating. In a subsequent work (Maley, 1972), he declared industrial arts to be the interpreter of technology. The subject would accomplish this by focusing upon major problem areas such as pollution, power generation, conservation, transportation, and communication. It would focus on "the application of technology in the solution of major problems facing mankind in the future" (p. 58).

This research and development approach was evident in Delmar Olson's version of what the new industrial arts ought to be. Olson (1972) wrote that:

> The new industrial arts confronts the student with challenges to attack real problems and issues consequential of technological advance impacting on man and culture. It is relevant to the student in his time. (p. 37)

There was need for a "Creative pedagogy" according to Olson, that would include "Employment of the processes of research and development in the search for truth and authority in technology" (p. 37). Along with presenting new organizers for the subject, Olson was also suggesting a new method. He had looked analogically to science for a model for thinking about technology. Research and experimentation, and the "search for truth," were to give way to problem solving and the technological method.

The disposition of the field here could be gleaned from a contribution in the 1988 yearbook of the Council on Technology Teacher Education, in which Hatch (1988) articulated the dimensions of problem solving. He asserted that:

> The technologically literate adult must also have a capacity for higher problem solving skills. The content of technology education should address technological problems and problem solving techniques through a variety of settings. (p. 97)

He charged the field to proceed in that direction.

The problem solving approach as described by Hatch foreshadowed a significant event in the curriculum history of the field. This event was marked by a consensus curriculum document, published in two parts, in which the content of the field was now to be framed by "the technological method" (Savage & Sterry, 1990a; 1990b). The technological method was essentially a problem solving model. Savage and Sterry deemed this as a "new departure" (Savage & Sterry 1990b, p. 10) in technology education. They wrote: "The new departure for technology education is 'process education' using the technological method. It requires students to think and act in a systematic fashion when solving problems" (p. 10). The authors continued:

> Process education using the technological method *encourages major shifts from content or subject matter based teaching and learning* (emphasis added) to a variety of educational opportunities and experiences for students such as thematic learning, problem solving, modular instruction, integration learning and cooperative learning. (p. 10)

Because this entreaty had the imprimatur of the ITEA, and because it was the result of the consensus among the top leaders of the field, it assumed great validity. In keeping with this new departure, Hutchinson and Hutchinson (1991) called for the field to break away from the content approach in favor of process. In a special JTE issue on curriculum approaches in the field, Johnson (1992) described an "intellectual processes" approach to the technology curriculum. He explained that an intellectual processes curriculum would be ineffective if it does not include a substantial amount of content knowledge. But indeed, this type of curricular approach invites the criticism that it goes against the grain of situated cognition by conceiving of learning as a decontextualized enterprise.

The fact that the ITEA stood behind the technological method as motif for the subject seemed to set technology education in the United States on a course quite familiar to British adherents, for whom process has traditionally been the primary curricular approach. "Design" has been a strong idea in British curricular theorizing related to technology. There is no attempt to articulate conceptual structure (see Department for Education, 1995; Eggleston, 1992, Jarvis, 1993; Roberts, 1994).

Whether through design or problem solving, the idea is to fashion pedagogy in keeping with the nature of technology. Of course there are difficulties with this line of thinking, especially when it means that design and problem solving are viewed formulaically or in linear fashion. Custer (1995) showed that all technological process are not of the same degree of complexity; but his view is not yet widely accepted. There is no question that intellectual process approaches can be eminently educative if executed *in the context of technology.*

These processes try to capture technology in action. They ask the question, "What do technologists do as they go about their work?" If the answer is that "they think" or "they solve problems," then the curriculum can proceed reasonably from there. The difficulty is that these answers are also true for what mathematicians or scientists do.

The truth is that we really do not know enough about the act of technological creation. And one very questionable premise of the field is that there is "the" single best technological method. Because technologies vary so much, originate from very diverse contexts, and respond to quite diverse circumstances, to posit that there is "the" method is mistaken. In practice many technological problems take years of toil to solve. The processes are more likely to be messy than clean. Critique along these lines is offered by Chidgey (1994), Hennessy and McCormick (1994), and Lewis, Petrina and Hill (1998).

The notion of "the" technological method is inspired by the quest to mimic science. But there is some contention as to whether there is even "the" single best scientific method. Bauer (1997) raised many issues in this regard, pointing out that within science there are several modes of inquiry depending upon a host of factors. Some sciences are young while others are old; some are data rich, others are data poor; some are observational, others are experimental; some are data driven while others are theory driven. The geologist proceeds in inquiry quite differently from the astrophysicist, who proceeds quite differently from the chemist.

In a scathing critique of laboratory-based science teaching, Hodson (1996) argues that process approaches such as discovery learning and constructivism misconstrue the real nature of science. He questioned whether a content-free approach to science, where students learn skills such as classifying, hypothesizing, inferring or predicting, and recording data, were transferable. The processes of science are not separate transferable skills, he argued. Thus:

> If we claim to assess the processes of science as separate skills, we are claiming that skill acquired in one context can be effectively used in another quite different one. If we made that kind of assumption in medicine, we would happily submit to a brain operation carried out by a specialist in obstetrics or psychiatry. In reality, the context in which skills are acquired is crucial to the proper performance of that skill and to our confidence in the practitioner. (p. 126)

Hodson argues that while it is true that science may have distinctive phases such as design and planning, performance, reflection and recording, and reporting, "doing science is an holistic and fluid activity, not a matter of following a set of rules that requires particular behaviors at particular stages" (p. 129). But this is a trap some have fallen into in technology education (e. g., Pucel, 1995). Problem solving is set forth as a series of steps to be followed by the student. But the process leading to the invention of a pacemaker for diseased hearts is not the same as trying to trouble-shoot an engine that would not start. In the one instance an algorithm might suffice, while in the other heuristics would be necessary. Problem solving processes are dictated by the nature of the problems, and by the ingenuity of the inventors and other technologists who pose and tackle them. We would be trivializing the idea of technology if children at least are not taught that.

Discussion

All school subjects have distinctive subject matter, though because of a longer tradition some have clearer structure and definition. All subjects can lay claim to arousing student imagination. Problem solving and critical thinking are integral processes in pedagogy related to science and mathematics, and probably to many other subjects. Design is a central aspect of art education. Hence, technology education has no special claim to generic intellectual processes. What distinguishes technology may be *the circumstances* that prompt design, problem solving, or critical thinking. Borrowing from Micheels (1978), it is the interplay of tools, materials, and ideas that gives the subject its distinctiveness.

Just as it is a mistake to try to position technology education next to academic subjects by claiming intellectual processes, it is also an error to think that it is the existence of a conceptual structure *per se* that legitimizes such subjects. Those subjects that have gained acceptance over time as school subjects have done so because of the perception that they are culturally significant; that is, they are consistent with civic ideals (Reid, 1992) or they are consistent with theories of progress (Kamens & Cha, 1992). Kamens and Cha (1992) pointed out that the non-academic subjects of art and physical education were able to diffuse the curriculum because beauty and fitness were ideals that were synchronous with theories of Western racial superiority.

Subject matter is only partly a technical concern. It is more than a mere compilation and classification of what there is to be known in a disciplinary area. Rather, subject matter is substantially a political concern, requiring contestation, negotiation, and compromises. Reid (1992) points out that subject matter must be filtered through several screens. National, local, and classroom concerns ought to be taken into account, as well as factors such as gender and race. Technology education in a poor country cannot be premised on the same content as in an affluent country.

If a subject were deemed to be a national priority, advocates would have little difficulty in installing it into the curriculum and teaching it in the way they wished. Technology is now a required, examinable subject for all children in England and Wales. The curriculum that has been agreed upon was a matter of negotiation among interest groups (see Department for Education, 1995). Subject matter was determined by debate. In Minnesota, the scope of technology education *in the schools* has now been dictated by a political process in which the technology education association of the state was able to make aggressive representation for the subject in discussions leading to state graduation standards (see Lindstrom, 1998). If school subjects are freed from the proprietary grasp of their advocates and their content released to a common pool, a result would be the dismantling of artificial barriers, increasing the possibility that coherence and meaningfulness in the curriculum will occur. Teachers would spend less time patrolling the borders of their subjects, and more time seeking to facilitate border crossings.

School subjects are not the same as the forms of inquiry that produce the knowledge their advocates seek to purvey (Reid, 1992; Stengel, 1997). Technology education is not technology as it is played out in Silicon Valley. Thus school technology does not have to be a mirror image of societal technology. It is of course desirable that the school subject bear authentic resemblance to its alter ego, but technology in schools should really be concerned most with exciting and delighting children. A preoccupation with running on the technological treadmill and keeping up with the latest equipment and software should be diminished.

Intellectual processes and subject matter are complementary curricular ideas. Both are important to understanding technology. However, there is a danger that both might be status driven, preoccupied with academizing the subject. These ideas seem far away from the center of what technology teachers do. It may be that they mask our shame. In a quest for status, we want to erase the blue-collar origins of the subject in favor of the white collar. But technology is an enterprise of practical intelligence and *making* is its essence. I would argue that pouring hot metal into molds is more representative of the subject than following a set of commands as a computer controls the movement of a robot arm. There is need for a curricular language that gives power back to that which makes the field unique. Cutting and bending and shaping and fitting, things that children do as they learn the subject, need to be given greater space. Curricular theorists resist the gritty aspect of technology education, retreating instead to a sanitary world. This is not the case in the schools, however.

Come Monday morning in technology education classrooms, teachers and their students meet once more to enact the subject. The better teachers make arrangements to allow for the varying interests and abilities of their charges. And once classes got going, the onlooker sees a hive of activity. In this milieu we find the essence of the subject. Content and processes are important of course, but they are not kept in separate compartments. Rather, these teachers see the subject as a whole. There is fluidity and curricular decisions will be made on the spot (see Holt, 1996 for how we might view this dynamic).

As teachers and their students interact, there is dialogue, give and take between them. In the midst of these dialogues and interactions, the curriculum comes to life. Machines are turned on and materials cut to length. Holes are drilled. Jigs and fixtures are proven out. Teachers are on constant alert for safety infringements. Students are free to talk, as in few other classes. Computers are turned on. Drawings are pored over.

Until we can capture and represent the subject as it plays out in the above scenario, come Monday morning in a typical technology education classroom, we will continue to miss the point about subject matter (see especially Holt, 1996). Admittedly, this scenario is clearly a biased version of what Monday morning might look like. It is laden with the curricular values of this author. There are certainly alternative scenarios. An increasingly common one is where, come Monday morning, the teacher gets out the curriculum supplied by one of the vendors of modular laboratories, looks up the lesson for that day, and the children turn on their computers and follow the prescribed activities, in clean rooms.

How teachers structure what they do on Monday morning depends on a host of variables, including the values they hold about the subject. Though there is probably no right or wrong in this discussion, there are certainly varying degrees of authenticity. What we should take from the thinking of Micheels is that, process or content, there is a central ethos of the subject. We approach that ethos when tools, materials, and ideas are at the core and the children are preeminent.

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Talking Technology: Language and Literacy in the Primary School Examined Through Children's Encounters with Mechanisms

Eric Parkinson

The Role of Language and Dedicated Terminology

Language plays a pivotal role in teaching and learning across the curriculum. This article embraces an examination of certain dedicated terms within technology education that children may encounter as part of their primary school experience. Four language-related issues are explored. The first of these concerns the difficulty that may be experienced in defining certain technological terms. The second concerns the ways in which primary school children use their own versions of terminology to describe specific artifacts and functions. The third issue concerns the role of some manufacturers and publishers in employing inappropriate terminology within educational products. The final issue revolves around the psycho-social development of language in young children and the contribution this may make to the acquisition of appropriate technical terms. These issues are woven together to form a complex linguistic tapestry with implications for classroom practice.

Language, when seen as the instrument of communication used by the speech community (Labov, 1994), provides the basic platform for the communication of ideas. Our language is packaged into words. These convenient vocal units express culturally-derived fragments of meaning, and indeed it seems that we all have an intuitive grasp of what constitutes a word as a distinct unit within our own language (Langacker, 1972). The use of the term "word" is qualified with culture, since it is the sharing of the meaning of our words in prescribed cultural settings that enables us to sustain the building blocks of our language. As Pinker (1994) said, "A word is the quintessential symbol. Its power comes from the fact that every member of a linguistic community uses it interchangeably in speaking and understanding…Words…are a universal currency within a community" (p. 151).

Within the community of the primary school, the core elements of language such as speaking, listening, reading and writing can be gained in all manner of subjects (DFE 1995, SCAA 1997a), including Design and Technology (SCAA, 1997b).

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Design and Technology has a significant stock of words that we could see as being of a "dedicated" nature. The words are often powerful and as "packets of meaning" we may assume that they need secure foundations upon which to erect complex structures of technological thought, language, and action. Many of the words employed in design and technology can be described as "terminology"—the naming of parts.

These technical terms are often a form of linguistic shorthand. We do not refer for example to "wheels which have machined or cast grooves disposed in a regular fashion around their periphery so they may interact with similar wheels in order to convey motion through the act of rotation." We simply talk about "gears."

The importance attached to individual words is recognized across curriculum documents in the United Kingdom. The national curriculum for England and Wales (DFE, 1995) suggests that pupils be taught "…to use the appropriate vocabulary for naming and describing the equipment, materials and components they use" (p. 59). Similar claims for the use of dedicated language are made in the Scottish Environmental Studies 5-14 program of the Scottish Office Education Department (SOED, 1993) and by the Department of Education for Northern Ireland (DENI, 1992).

On the basis of core directives such as these, if children are to begin to develop a design and technology vocabulary it seems important that the meanings of words that they accumulate are precise. Moreover, the vocabulary should be practiced regularly within appropriate settings to better embed them as core linguistic components. This dedicated stock of words, the terminology of design and technology, could be quite extensive even for children of primary age since curriculum expectations may embrace conceptual content of a relatively high order. Areas such as "mechanisms" and "control applications" carry a significant stock of technical terms which primary age children may encounter.

Words, Contexts, and Expectations

We do of course often see that certain words are used in one way in a subject-related circumstance but have different meanings when the context is more general. The term "energy" for example, has a specific, reserved meaning in science. Yet it has a very unscientific range of applications beyond that discipline when children in class claim they "have no energy today!" Nonetheless, effective teaching and learning should still have enabled the child to gain a grasp of the notion of the principle of the conservation of energy. The word "energy" in the dedicated scientific sense is loaded with meaning and shared across the scientific community.

Perhaps it is one of the features of higher language acquisition that we may employ various levels or domains of vocabulary usage. Through some subtle mechanism, terms can be shared in certain contexts, but when appropriate we are able to throw a subtle "linguistic switch" to accommodate an alternative set of meanings in different settings.

In the primary years of education, from the perspective of published guidance, there seems to be something of a presumption that accumulation of a precise technological vocabulary should be undertaken. Moreover, since there is not much evidence to the contrary, it would appear to be a straightforward process. Thus in primary schools where there can be a considerable repertoire of activities in designing and making, it would seem that children, while engaging in these various tasks, should have access to teachers, support texts, and perhaps even software that could introduce "appropriate" vocabulary. These assumptions may, however, not be consistent with what actually happens in primary school practice.

Developing a Technical Vocabulary Through the Concept of Mechanism

For the purposes of this article, the linguistic focal point will be two terms which are central to the understanding of aspects of mechanics at primary education level. Encounters with mechanisms play a part in United Kingdom primary schools from the early years with simple vehicles to later, more complex engagements with control technology (Järvinen, 1998). At a conceptual level, mechanisms are part of our technological society and embrace core ideas on the transfer of energy and the application of force. Engagement with mechanisms in school settings can be one of the very practical routes by which scientific understanding can be gained through interaction with technology.

Intimately bound up in the conceptual areas of force and energy relating to mechanisms is the idea of relative motion. Parts move relative to each other and do so predominantly by describing circles or parts of circles. Two terms, which are important in the understanding of the vocabulary related to mechanisms, are "shaft" and "axle." There is a body of evidence to suggest that terms such as these, in certain texts, lack clear meaning. As a result, published support materials may be unable to use the terms in an appropriate manner in teaching and learning situations.

Problems of Definition—The Meaning of "Shaft" and "Axle"

The origins of the terms shaft and axle are based in antiquity. Partridge (1958) indicated the origins of the term *schaft* from Middle English, from Old English as *scaeft* and Old Norse as *scapt.* In the case of Old Norse, the term refers to a long handle—usually that of a spear. Further into the past one can find the Latin term *scapus* and the Doric Greek term *skapon,* both meaning "staff." A modern source such as Chambers 20th Century Dictionary (1983) refers to a shaft as "anything long and straight: a stem: an arrow: a missile…a rotating rod that transmits motion" (p. 1189).

Beyond the basic qualities of "long and straight" the term "shaft" then, clearly has a range of meanings and these are often context-dependent. From a structural perspective, the term shaft could embrace the long and straight pieces that contribute to a framework. On the other hand, a shaft can describe a long, straight *void* such as a mine shaft. And then there is the mechanically dedicated meaning. In this instance the long, straight component is further qualified in that it rotates and thus can transmit motion.

The term “axle” was shown by Partridge (1958) to have Greek (*axon)* and Sanskrit (*aksas)* origins, and modern dictionary definitions such as the Chambers 20th Century Dictionary (1983) clearly relate *axle* to *axis* and describe it as “…a line about which a body rotates, or about which a figure is conceived to revolve” (p. 86). The Collins English Dictionary (1991) specifies the term in the context of mechanics such as “a bar or shaft on which a wheel or pair of wheels, or other rotating member revolves” (p. 107).

From these core definitions, in the contexts of mechanisms, it can be established that shafts can be long straight rods that transmit rotary motion. Axles on the other hand, although they *may* be long and straight, do not turn. Rather, things turn around them.

There is a contradiction however. Perhaps as the ultimate reference, the Oxford English Dictionary (1989) describes an axle in a mechanical context as “The centre pin upon which a wheel rotates, or which revolves along with it” (p. 839). From the Oxford English Dictionary reference it seems that an axle may be fixed *or* it may rotate.

This confusion is intensified by terms used in the realms of engineering. For example, an engineer may speak of a “live” axle or a “dead” or “fixed” one. However, in this respect at least the term is qualified so that the user is aware of the implications of the “types” of axles. In engineering terms, especially within the automotive industry, this qualification “live” is used in the description of, for example, a “live rear axle.”

As a final complication to this picture, in the heavy transport sector, a railway carriage or wagon will be seen to have “axleboxes” on the outside of frames, and yet, turning within these bearing structures are rods (shafts) which firmly connect pairs of wheels!

Examples of Definitions from Texts to Support Technology Education

As a means of supporting primary teachers, the UK-based Design and Technology Association has published a useful guide for primary educators regarding terms used in Design and Technology activities that may be encountered in the classroom. From this source, The (British) Design and Technology Association (DATA) (1995) offers the following definitions: “Axle - Rod on which one or more wheels can turn” (p. 22) and “Shaft - A rod which transmits motion” (p. 25).

With core dictionary definitions in mind, one might be compelled to ponder the meanings of the terms and wonder what ideas they convey to primary teachers. The DATA shaft definition is a little less specific than core dictionary definitions. While a shaft clearly *is* a rod that transmits motion, this motion is not qualified as being rotational.

Not *all* rods which transmit motion may be shafts. Rods which transmit motion by moving to and fro, such as a push-rod or a connecting rod, exist. In the language of mechanical engineering, then, the term “rod” seems to have a range of applications when given further qualification.

“Rod” is a rather useful non-committal term, for a rod is long and straight, and if it rotated it *could* act as a shaft. On the other hand it could be the axis upon which something else rotates in which case it would make a useful axle. Rods could even be used to describe long, straight structural elements.

The term "axle" under the DATA definition *may* be inexact, depending upon which definition one adheres. Certainly the extended understanding of axle that is used in some sectors of engineering may need further qualification via "dead" or "fixed" and "live." The whole basis of ascribing meanings to multi-sense words is a discipline in itself and the process of establishing the senses of words for dictionary entries is a complex business for the domain of a specialist. Large, general language sources offer the lexicographer a resource which can provide a systematic approach to establishing senses. Atkins (1987) for example provides an insight into the use of objective (syntactic and lexical) evidence to support dictionary senses.

On the basis of complexity, the "naming of parts," or terminology, is relatively straightforward and at the "easy" end of the semantic scale. However, even at this level, a set of definitions that is the basis for constructing a technological vocabulary seems quite difficult to achieve. In light of this, is it realistic to expect that teachers will comprehend a range of meanings and be able to pass on accurate information to children?

Terminology Used by Primary School Children Based on Work with Moving Things

Much design and technology activity in the primary classroom centers around moving things for they are quite simply a source of inspiration for children and teachers alike. Even before the text of a national curriculum for England and Wales began to specify the skills and content of design and technology at the start of the 1990s, teachers and children had been engaging in the process of making things "go" for years. The justification was simple. Wheeled vehicles were interesting in their own right and perhaps reflected the aspirations of an increasingly mobile "car-centered" population (Parkinson, 1998). Young children pushed simple wheeled toys and went on to make things "go" very often from the assured platform of success offered by construction kits. As manipulative skills developed, children were able to represent and create a wide variety of wheeled vehicles using a range of reclaimed materials.

Perhaps in the broadest sense there is an element of progression in all of this. First, children are able to relate to aspects of motion by wheels interacting with a flat surface such as the ground or a desktop. Play activities enable them to gain an intuitive understanding of the differences between sliding and rolling friction and the key role that wheels play in all of this. At some point in a learning sequence, children become able to handle the more abstract notion of wheels *interacting with other wheels*. This interaction occurs either by wheels turning on fixed axles or the wheels may be attached to shafts (or "live" axles). In the latter case, there is an advantage to be gained from shaft-driven elements in that once a shaft is turning then specialized wheels of different sizes, such as gears, can occupy places on the *same* shaft. Thus they can transfer motion from one shaft to another in a complex sequence of drive relationships we call a gear train.

In a study of primary children engaged in problem solving with gear trains using LEGO Technic, Bennett (1996) provided an account of the descriptive terms employed. He stated that, "It was interesting to note the reluctance or inability of the children to use the technical vocabulary in discussions. Axles were variously called *'stick things'…'spars'…'that bit there'… 'Little things-what's it called?'…*and yet this did not necessarily diminish the children's practical capabilities or willingness to explain their understanding" (p. 228). The Bennett study was undertaken with a small group of children in a spare classroom and videotaped. This controlled setting may have, of course, influenced the language-related outcomes.

In a similar mechanism-related setting for studying primary-age pupils' linguistic behavior and responses, Schoultz (1997) reinforced this view of children choosing to use their own terminology. He did this from the perspective of technological language not being seen as a native language. Within this study, children were invited to interact with a "black box" containing a mechanism and then to provide explanations for what was presumed to happened within. When interviewed about what might have been happening within the black box, Schoultz stated that, "The pupils in the study used few words from the technological field, instead they used words like that one, this one, this stick and that spike etc. This is not unusual as technology for many people is a long list of words and terms which have been extracted from their context" (p. 28).

The picture starting to emerge here is that children are not using "correct" technical terms. This observation is underlined in England and Wales by the government Office for Standards in Education (1995) inspection force which raises this issue of the acquisition of technical vocabulary from their own particular observation-based perspective, pointing out for example that in infant schools (Key Stage 1) "…technical vocabulary was rarely developed adequately" (p. 6).

Data collected specifically for this article from a small sample of institutions in Kent, UK, supports the view that pupils—and their teachers—show limited application or understanding of the terms axle and shaft. To assess pupil and adult understanding of these terms, timber artifacts featuring a wheel which turns on a yellow axle and wheel attached to a red shaft were produced.

Samples of children and adults were randomly selected from co-operating institutions. The subjects were asked to explore the artifact and then give a name to the red component and the yellow component.

Reactions from children

The initial response from children regarding the naming of parts was in many ways secondary to their reaction to the artifact itself. Most children wanted to provide a name—or perhaps a context for the whole artifact. Even though the wheels were offset on opposing corners of the artifact, and only one wheel was evident on each rod, many children ventured that "*this is a car isn't it?"* Some ventured further that "*some wheels are missing*."

The children were initially unwilling to accept the abstraction and detachment required to focus on individual components; these had to be related to the whole artifact and to them, the device seemed to be "incomplete" without a name or purpose.

Analysis relating to the categories of name offered by children for the red and yellow components was undertaken under the denotational structure described by William Labov in 1978, cited by Allan (1986). Labov indicated ways in which descriptive terms might be applied to a set of containers. His evidence suggested that decisions on the how to assign various names might be made according to the criteria of shape, material from which the containers were made, the purpose of the container, and the location of the container.

On a small sample of children (*n*=18) in UK primary years 5 and 6, an analysis was carried out upon data provided in the naming activity. Since the Labov criterion of "place" seemed inappropriate (although this was perhaps a pointer to the matter or "context" which was not pursued further for the purposes of this study), the classification was attempted using the criteria of shape, material and purpose.

This task proved to be largely ambiguous for it was often impossible to clearly assign the terms used for the red shaft and yellow axle to the Labov criteria. Children used terms such as "handle"—which could apply to either (or both) criteria of "purpose" or indeed of "shape." Similarly, some children referred to the rods as a "wooden pole." This could be classified under "material", "purpose" and "shape!"

From the sample, one child referred to the fixed and moving rods as a "shaft." No children used the term "axle." The terms most frequently used were "piece/bit of wood" (5 responses, two for the shaft and three for the axle) and "stick" (4 responses, two each for the shaft and axle).

A second sample (*n*=31) was collected from younger children. These were drawn from UK primary years 3 and 4. The pattern of data reflected that found with the previous sample. The most frequently used term was "wood" (15 responses, seven for shaft and eight for axle) and "stick" (11 responses, seven for shaft and four for axle). No children used the terms "axle" or "shaft."

The sheer *range* of words used by children as descriptors was extensive in both samples, and provided a glimpse into the richness and diversity of language upon which they were able to draw. This could be seen as a stage in children's concept development in which, according to Vygotsky (1986) the children were able to use concrete and factual bonds to associate with components, rather than adult abstractions and logic.

Comparison with data from adults

For purposes of comparison, data were also collected from serving teachers. Volunteers in two primary schools (*n*=28) teaching the 5-11 age range in Kent, UK, kindly provided information. The overwhelming finding was that of the use of the preferred term "axle" for both the red shaft and the yellow axle. These data from serving teachers was further supported by data volunteered from students (*n*=108) in the first few weeks of a primary teacher training course at a higher education facility in Kent. Again, the overwhelming response was that of the use of the term "axle" to describe both the red shaft and the yellow axle. In fact, for the red shaft, 46% opted for the pure term "axle" while a further 20%

used the term, but in qualified form such as " moving axle." For the yellow axle the use of the term "axle" was slightly less emphatic, with 24% using the unqualified pure term and a further 26% using it with qualification.

In the situations described so far, primary pupils could be seen to be participating in an informal labeling process. Descriptive terms could be seen to be woven into terse phrases so that meanings can be shared within a practical setting, often rooted in problem solving. When we observe children working in group situations at mechanism-related tasks, body language such as pointing plays a significant role in addition to spoken language. Johnsey (1998) elaborates on this aspect of body language which augments, extends, or substitutes speech as a transfer medium for ideas. He suggested that, "Hand gestures can describe the dimensions and shape of a model and how parts of it function and move. The method is a quick and effective way of communicating ideas to others and of manipulating an image held in the mind's eye" (p. 62).

An Analysis of Shaft and Axle Terminology in Mechanical Kits

The basis for definitions has been seen to be somewhat problematic. A review of selected literature does nothing to clarify this situation. Three examples concerned with publications intended to educate students in matters mechanical were selected for study.

The first example is drawn from the work of the Rev. Robert Willis, Jacksonian Professor of natural and experimental philosophy at the University of Cambridge in the mid 1800s. Willis developed a special construction kit which could be used a means of demonstrating principles of mechanisms to his students. It was devised so that mechanical components could be added, removed, or re-positioned with speed and accuracy during a lecture-demonstration.

This demonstration apparatus was described in great detail (Willis, 1851) and provides insight into the basic terminology used. Willis suffered no confusion between axles and shafts. His explicit text makes it very clear that within the context of mechanisms, shafts can rotate and need suitable bearing points and sometimes a means of inhibiting undesirable to and fro motion along the long axis. He wrote, "To prevent the endlong motion of the shafts, which are mere plain cylinders unprovided with shoulders or necks, rings must be employed. This device is usual in manufacturing mechanism when a shaft requires to be often taken out for cleaning or adjustment. It is plain…the shaft will be free to revolve, but prevented from sliding endlong" (pp. 24-25).

The Willis example has been chosen since it was something of a benchmark in education in mechanics. Willis was a clear leader in his field, established a novel, practically-based teaching mode, and communicated his ideas to an influential cadre of future engineers. Moreover, for the benefit of his students, Willis did not use the qualified term "live" axle, he used the dedicated and specific term "shaft."

A second example is drawn from an instructional handbook concerned with the product "Mecanno." Meccano, a set of metal parts originating from the start of this century, was in many ways the first construction kit to gain mass appeal both for children and indeed for many adults. It held a leading place in the global market until being displaced by construction kits made from injection-molded plastics in the 1960s.

The example drawn from the Meccano Constructors Guide (Love, 1971) then, represents a significant point of accumulated knowledge and application of the Meccano product. It featured the most modern Meccano set, one that used electric motors and lights. In many ways, this was ground-breaking territory for the late 1960s and early 1970s. Here was a product, with supporting literature, that could influence a whole generation of potential engineers.

The Guide is confusing on the issue of specific mechanism-related terms. Within the metallic domain of Mecanno, wheels, gears, and pulleys can be fixed to metal rods with small screws. This implies that rods could be given the specific term "shafts," for they can rotate in holes in the structure provided by the perforated strips and plates which are characteristic of the Meccano construction system. Alternatively, the rods could have been described as "free" or "live" axles." The Guide features copious illustrations of mechanisms with shafts. In the text however, these shafts are referred to as *Axle Rods*. To simply have called them *rods* would have been acceptable, but to qualify the term "rod" with a further descriptor seems difficult to justify and indeed rather clumsy.

Rod has an almost elegant simplicity as a term. Perhaps the author wished to qualify the general term rod with an indication of motion, and chose axle to do this. Nonetheless, did this rather ponderous piece of language-giving affect a generation of Meccano-inspired potential engineers?

The third example in this historical succession is drawn from what could be seen as one of the successors to Meccano. This product is LEGO Dacta, which became popular in the 1960s and 70s as a children's toy. Later, this product achieved significant penetration into the formal education market.

For the purpose of the LEGO example, two publications produced by the LEGO organization were selected. The first publication is the *Teacher's Guide to TECHNIC 1* (LEGO Group, 1985) for children of the ages of seven and upwards. This product marked a departure of LEGO away from the interlocking building blocks with a focus on modeling structures and into the modeling of mechanisms. This transition clearly put them into the educational market.

Moving parts in the LEGO system, particularly in the *TECHNIC 1* set, are characterized by the use of precision-made, black, splined rods onto which various types of wheels can be pushed so that they hold their position by friction. These splined rods can then rotate freely in the regularly pierced plastic structural members of LEGO. These splined, black rods are shafts (or "live" axles).

However, according to the Teacher's Guide for TECHNIC 1 the black rods are known simply as "axles." This seems like an educational opportunity missed. A dedicated term could have been used, but the unqualified "axle" was employed instead.

Have things changed since 1985? Very little it would seem. The text of a later guide, the LEGO DACTA Motorized Systems Teacher's Guide (LEGO, 1994) is part of a class resource which demonstrates the full capability of a precision-made injection molded plastic kit. This resource is for use by secondary school pupils. The Guide acknowledges that the Motorized Systems set has arisen out of international collaboration between LEGO Dacta teams in Denmark, Australia, and the UK. In a situation perhaps similar to Meccano of the late '60s and '70s, one is dealing with a construction kit at its zenith.

As before, the text of the Guide however refers to the black splined shafts which characterize LEGO mechanisms as unqualified "axles." The reader is advised for example that "Axles should be run as freely as possible to reduce friction…" (p. 13).

One is forced to repeat the reservations expressed regarding the construction guide for Meccano. How will this affect the language acquisition of a generation of engineers who have grown up using LEGO Dacta materials? The situation has further implications since the instructional materials are for teachers. As a consequence, teachers could acquire unqualified and inappropriate technical vocabulary and convey it to the children they teach.

Reflections on Evidence in Relation to Psycho-Social Influences

From the standpoint of the diversity and range of names produced by children for "putting a name to" unfamiliar components, it is useful to reflect on the self-devised informal terms used by children in the previous examples. Shape and function certainly play major roles as descriptors for the construction of informal labels. These are "working" labels which serve the children in their own particular context and socio-linguistic setting.

The investigations on children's performance on thinking and language in controlled, perhaps unfamiliar, laboratory-like investigations described earlier (for example contrived pieces of problem solving and children responding to interviews and the handling of unfamiliar artifacts), require careful reflection. Lave (1988) offers a reminder that the learning process itself can be seen as part of an interaction between complex mental process and the totality of the learning environment. Data recorded from contrived learning situations may not represent the broader, more complex picture. This is not to say that children's engagement with the unfamiliar is of no value. Within the field of problem solving, Hennessy and McCormick (1994) provide a reminder that changing familiar aspects of tasks (such as introducing the frames with yellow and red rods or the "black boxes" described earlier) can assist in the development of decontextualised knowledge, enabling learners to master complex situations.

A significant factor to consider regarding the complex overall picture of language learning is that of *assumptions* about the use of use of everyday language. Rix and Boyle (1995) raise the issue of children having alternative meanings for *everyday* words. From the context of primary science they said "…we became intrigued by the number of times children appeared to have alternative meanings for everyday words which we took for granted needed no further explanation to make the meaning explicit" (p. 19). The notion of *alternative* meanings signals the inclusion of another strand in the understanding of learning and key role of language, for it is primary science that has left an indelible mark on the research landscape with ideas on constructivism. This rests on the notion that learners assemble their own frameworks of meaning (Driver et al., 1985) in order to explain the circumstances of their surroundings. Moreover, scientifically incorrect, yet plausible explanations may lead to the development of alternative frameworks. These must be challenged and appropriately reconstructed if scientific ideas are to take root and flourish.

From this standpoint, a parallel line of inquiry can be followed. If it is accepted that children may construct their own meaning, then it may follow, given the interaction of meaning and language, that they may construct elements of their own language too. This might well include an array of informal names supported by the qualification of concrete descriptors. Within this linguistic construction process the accuracy of words will be significant. Indeed, as Sutton (1992) crucially pointed out, it will occur at times of episodes of new thought that *shades of meaning* will be at their most significant. He stated that, "a shift of attention from one shade of meaning to another is what initiates new understanding" (p. 57).

Halliday (1975) brings a further dimension to the notion of informal labeling. In describing two "macro-functions" of language, a distinction between functional components of the semantic system is made. The first of these macro-functions, the "ideational" components, where the speaker expresses experiences about the external world, would seem to match well with the labeling process—the notion of matching parts to informal "name plates" based on criteria such as shape and substance.

The second of these macro-functions within the semantic system refers to "interpersonal" components. This function is characterized by participation in a speech event where elements of personal judgements and attitudes can exert effects on the listeners. Is this process also at work when informal labeling is undertaken? Within the nuances of spoken language, then *how* things are said may be as relevant as *what* is said. Phrases such as "little things," "what's it called?" and "stick things" may convey interpersonal overtones into the informal labeling process. Medway (1994) identified the ideational component in a positive light in the context of architects engaged in building projects. He described types of communication scenarios in which architects engage with each other and suggested that the ideational and interpersonal linguistic strands weave together to form a textual web with "…strands of meaning appearing and reappearing in successions of contexts" (p. 92).

Situated Learning

Lave (1991) added another dimension to this aspect by taking a de-centered view between the polarity of constructivism, and individual and socially shared cognition. Lave suggested that children may develop language and learning within what is termed a "situated community of practice." This may share some similarity with the architects' office with its community of specialized engineers and designers sharing tasks, contexts, and a stream of specialized language.

From a classroom perspective, this may have implications for the way that teachers organize practical learning situations, such as engagement with mechanisms. Perhaps the role of pupil *participation* needs further exploration with a greater emphasis on organizational strategies that enable pupils to situate themselves both as observers and as managers with responsibility for practical activity (Lave & Wenger, 1991). Rogoff (1995) reinforced this view as one of the basic notions concerning the transfer of knowledge and made the point that it is the transfer between situations of say, "observer" and "responsible organizer" that allows participants to construe relations between purposes and meanings. Indeed, Rogoff described this process in a profound way as being "…inherently creative, with people actively seeking meaning and relating situations to each other" (p. 159). The situated learning environment can thus enable episodes of "reflected" dialogue in which ideas are tested by bouncing them onto other participants to gauge levels of acceptance.

Conclusion

We are left with a number of problems. First, from one perspective it would seem that linguistic possession of sets of appropriate technical terms is a desirable curriculum aim. Second, as has been demonstrated from the selected examples, there is some inconsistency in the very definition of technical terms themselves. In the limited setting of the cases presented, for example, one cannot be sure what "right" terms actually are! Third, the guidance materials that could influence and direct the actions of teachers reflect the general uncertainty over the use of technical terms. They are inconsistent. Finally, from limited research evidence based on observations of what children do in schools, children appear to want to use their own terms rather than prescribed ones anyway. They are able to construct their own terms based, for example, on perceptions of form and function. This in itself is a valuable learning experience which may serve to develop technological capability.

What effect does all this have on development of language and literacy within the primary classroom? It may be that children are not necessarily "technologically deprived" if their technical vocabulary is not as sound as curriculum documents might incline us to believe is desirable. Perhaps the technical "home grown labels" produced by children within the design and technology "situated community of practice" contributes to a growth of understanding that is, as yet, not recognized nor understood. A body of further research from primary classrooms needs to contribute to the overall picture. Indeed perhaps the pursuit of a true technical vocabulary at an early age is, to an extent, undesirable and special terms are best used in the more refined atmosphere of the secondary school. Here technology-dedicated staff can use appropriate terms and convey these to children consistently within relevant contexts. It is possible that the "misuse" of technical terms in settings that educate young minds has itself contributed to the occurrence of "linguistic drift" which seems to surround the terms specified in this account.

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