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Contents

From the Editor

Articles

Book Review

Miscellany

From the Editor

Affect, Terminology, and a Bit of Tongue-in-Cheek

When our grandchildren Jacob and Danielle, now aged six and ten respectively, come to visit we often end up working with tools and materials to solve “technological problems” that they have thought up. Sometimes we work at home in my shop in the basement and sometimes we work in the lab at the university. These occasions are always pleasant and inevitably they cause me to reflect on the fact that the same reasons that attracted me to this field some 40 years ago are every bit as strong in my heart today.

What impresses me most in these intimate sessions with my grandchildren is the excitement that they show during the process of solving a technological problem, and especially when they have made a successful solution. I cannot think of another teaching area in which this phenomenon occurs, at least not with parallel intensity.

Around the world, there is increasing pressure these days to demonstrate that what children learn is important and that they are, in fact, learning. This is certainly true in technology education where the dearth of supportive research has put the field at a disadvantage. Explanations for this shortcoming have appeared over the years in this Journal, not the least of which is the fact that few resources have been available. In the US, for example, considerable money has been available to develop instructional programs and to prepare teachers in their use, but the support to actually conduct research has been quite minimal. Things are apparently about to change with a new direction being taken by the National Science Foundation.

Whether the efforts are funded or not, qualitative methodologies continue to grow rapidly within the educational research community. The reports of research in the JTE are no exception to this growth, with most of them coming from authors outside of the US. Reading these reports that describe the thinking and reasoning that students go through in solving technological problems can be very informative and thought provoking. They epitomize the type of reflective thinking in which all teachers need to be engaged. It seems that such research is at the brink of addressing how students *feel* about the technological problem solving process, why they are so intensely excited about it, and how it changes their feelings of self confidence and self worth. In other words, technology education may provide the ideal environment in which to address the *affective* domain of knowledge through the application of qualitative research methodology, breaking the long tradition of nearly exclusive emphasis on the cognitive domain. With the emphasis on *doing* that continues in most of our programs, research in the psychomotor domain continues to be a natural fit as well. In short, technology education seems to be an ideal and unique test bed for qualitative research that integrates all three domains of knowledge, as well as thereby being an exemplar of ideal teaching practice for other disciplines.

Trying to synthesize the qualitative research that has been done in technology education and derive principles from it are difficult and formidable challenges. Applying the principles thus derived to educational practice in a meaningful way is likewise daunting. Part of the problem in making sense of qualitative research is related to terminology. The novice has a difficult time entering the arena due to the elusive and inconsistent nature of the terminology used. The terms are often not found in ordinary dictionaries. What's more, if one happens to leave the qualitative research community for even a relatively short period of time, a whole new vocabulary seems to appear upon reentry. As with any field that has not yet reached maturity, the terminology of qualitative research continues to evolve.

The ever-changing terminology of qualitative research caused me to reflect on the terminology of technology education and some its anachronisms and unclearness. In fact the issue is not a new one, for a committee headed by William E. Warner took on the charge of trying to make sense of it all back in 1929 (see Barlow, 1967, pp. 267-268).

The term "technology education" itself is an interesting starting point in reflecting about terminology. Both "technology" and "education" are nouns, making the term impossible to translate into quite a number of languages, including Spanish and Finnish - languages with which I happen to have some personal experience. "Technological education" is grammatically correct and is used by some of the international authors who have published in the JTE.

In the secondary schools, students do not refer to the classes they are taking as "science education" and "mathematics education." Instead they simply refer to them as "science class" and "mathematics class." It seems that simply using the term "technology" and "technology class" would be appropriate, though there are some obvious problems in consistency when it comes to "physical education." Nonetheless, it seems that just "technology" is appropriate for the secondary schools whereas "technology education" would seem appropriate in reference to programs that prepare technology education teachers. Some have used or suggested the term "technological studies." Though this term may make sense outside the schools, inside it does not – school students assumedly "study" all the subjects in which they are enrolled.

In the US, the use of the term "laboratory" or "lab" has been favored over the term "shop" for decades to describe the physical facility in which technology education (i.e., technological education) instruction occurs (again, see Barlow, 1967, p. 268). I will continue to insist that my students use the term "lab," as I have done for most of my career. One of the arguments to support this is that a laboratory is where new ideas are developed, whereas a shop may be thought of a production facility where the work is often repetitive and boring. As with all terms, each person constructs their own personal definitions, with their own connotations, based on their life experiences. For me, “lab” does not conjure up particularly exciting memories, since I can connect it with bad experiences I had doing chemistry experiments in a school lab. Likewise, my wife worked for over a decade in a quality control lab in an industry. She performed the same chemical analysis tests over and over, day after day. Though being a “shop teacher” is a disdainful term for many in the profession today, there was a time when teachers were rightfully proud of being identified as such. Developers of popular software programs such as Photoshop (Adobe Systems Inc.), Print Shop (Broderbund, LLC), and Paint Shop (Jasc Software Inc.) apparently see marketing potential in the use of the term and all three products are promoted as “creativity tools.”

There is redundancy in some of the terms we have used as well. In an earlier attempt to upgrade the field, material-identified courses such as woodworking and metalworking were renamed “woodworking technology” and “metalworking technology.” If one accepts a definition of technology in terms of human action, then technology is redundant with the “working” part of these terms. Some might even argue that the term “design and technology,” parallel to technology education in England and other countries, is also redundant. How can one engage in technology without design, or vice-versa? Likewise, some are using the term “Design and Engineering” – the redundancy is self-evident.

Then there are “sound bite” terms that are intended to attract one’s attention, but may not communicate anything to the recipient about what the terms mean. “Synergistic Systems” is the name of a popular instructional system in technology education in the US. However, it does nothing to describe the program itself or even to place it in the context of education. “Project Lead the Way” is another example. Such terms can attract attention and raise curiosity, but they are successful in meeting their ultimate intent only if the means are immediately available for the receiver to make sense of them.

Some of sound bite terms were date stamped, like the name of the large computer manufacturer, Gateway 2000, which changed its name simply to Gateway when the year 2000 arrived. A parallel in technology education was a program titled “Lab 2000.” Some terms, though fixed in time, go on into perpetuity. For example, many people still “listen for the dial tone” and “dial the number.” They also refer to computer diskettes as “floppy,” even though the last ones that actually flopped were the 5_” diameter variety that became obsolete about a decade ago. “Silk screening” is still used on occasion instead of “screen printing,” even though silk has not been used in the process for decades. The piping medium that carries water away from the foundation of a building is called “drain tile” even though for years it has been made of plastic rather than fired clay.

Back to my grandchildren… Jacob was the one who provided the idea for this essay. While we were watching television in our family room a few months ago, he said, “Grandpa, do you think we could go down in the basement and build something in your *lab*?” Hmmm…

JEL

Reference

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Articles

Effects of Take-Home Tests and Study Questions on Retention Learning in Technology Education

W. J. Haynie, III

The benefits of tests as aids to retention learning, beyond their primary evaluation function, have been studied in a variety of settings. This study sought to isolate the effects of take-home tests within a technology education context. The investigation involved instruction via self-paced texts, initial testing of learning, and delayed testing three weeks later. The delayed tests provided the experimental data for the study.

Background

Most of the research on testing has concerned standardized tests, but much of the evaluation done in schools is with teacher-made tests (Haynie, 1983, 1990a; Herman & DorrBremme, 1982; Mehrens, 1987; Mehrens & Lehmann, 1987; Moore, 2001; Newman & Stallings, 1982; Stiggins, Conklin, and Bridgeford, 1986). Research is needed on the effects of teacher-made tests and other issues surrounding them such as frequency of use, quality, benefits for student learning, optimal types to employ, and usefulness in evaluation. The available findings on the quality of teacher-made tests cast some doubt on the ability of teachers to perform evaluation effectively (Carter, 1984, Fleming & Chambers, 1983; Gullickson & Ellwein, 1985; Haynie, 1992, 1995b, 1997a; Hoepfl, 1994; Moore, 2001; Stiggins & Bridgeford, 1985). Despite the recognized faults, Mehrens and Lehmann (1987) point out the importance of teacher-made tests in the classroom and their ability to be tailored to specific instructional objectives. Evaluation by teacher-made tests in schools is an important and needed part of the educational system and a crucial area for research (Ellsworth, Dunnell, & Duell, 1990; Haynie, 1990a, 1992; Mehrens & Lehmann, 1987; Nitko, 1989).

The effectiveness of test taking as an aid to retention has been studied in several settings and in association with several related variables. In many of these studies, test taking has been shown to aid retention of learned material (Haynie 1990a, 1990b, 1991, 1994, 1995a, 1997b; Nungester & Duchastel (1982)1982). Reviewers of some earlier works which used the general protocol

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of this study in a technology education setting to examine the benefits of various types of tests criticized them by pointing out that experimental groups in many of the studies expected to be tested whereas the control groups did not. The logical argument was that students in the experimental groups paid more attention to the study of the material and thus, it was difficult to separate the gains made while studying more diligently from those claimed by the investigators to result from the act of taking the test. Only one of those studies demonstrated a clear separation of these two factors (Haynie, 1990a), and it was conducted in a secondary school setting with videotaped materials as the teaching-learning method. Another criticism of the protocol was that students did not expect the test scores to be counted in determination of their course grades, so they may not have taken the entire unit of instruction seriously. Lastly, in most of the earlier studies, no attempt was made to insure equal ability of the groups when they entered the study other than randomization of treatment assignment. This investigation examined some new, related questions with careful attention to address these criticisms.

Purpose and Definition of Terms

The purpose of this study was to investigate the effects of take-home tests, in-class tests, and study questions used in anticipation of an upcoming test as aids to retention learning. "Retention learning" as used here refers to learning which lasts beyond the initial testing, and it is assessed with tests administered two or more weeks after the information has been taught and tested (Haynie, 1990a; Nungester & Duchastel, 1982). A delay period of three weeks was used in this study. "Initial testing" refers to the commonly employed evaluation by testing which occurs at the time of instruction or immediately thereafter. "Delayed retention tests" are research instruments which are administered two or more weeks after instruction and initial testing to measure retained knowledge (Duchastel, 1981; Haynie, 1990a, 1990b, 1991, 1994, 1995a, 1997b; Nungester & Duchastel, 1982). The delayed retention test results were the only data analyzed in the experimental portion of this investigation.

The research questions posed and addressed by this study were:

1. If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning better when in-class or take-home tests are given?
2. Do students study and prepare differently depending on the type of test that they expect to take?
3. Can the effects of differing study methods be detected in delayed retention tests?

Methodology

Population and Sample

Undergraduate students in 16 intact technology education classes were provided a booklet on "high-tech" materials developed for space exploration. Four intact classes were combined into each group to minimize the effects of variables such as time of day, which graduate assistant conducted classes, and semester in which the course was taken. There were 279 students divided into four groups: (a) No Study Questions, Multiple-Choice (M-C) Test Given (Group A, *n* = 71), (b) No Study Questions, Take-Home Test Given (Group B, *n* = 71), (c) Study Questions Given, No Test Given (Group C, *n* = 70), and (d) No Study Questions, No Test Given (Group D, Control, *n* = 67). All groups were from the Technology Education metals technology (TED 122) classes at North Carolina State University. Students were freshmen and sophomores in Technology Education, Design, or in various engineering curricula. Students majoring in Aerospace Engineering were deleted from the final sample because much of the material was novel to other students but had previously been studied by these students.

Group assignment to instructor was not randomized due to scheduling restraints, however, all sections were taught by either the researcher or his graduate assistants—each teaching some control and some experimental sections. The course instructor gave no instruction or review to any groups and provided the directions for participation via a scripted standard statement. Four sections were in each experimental group. Random assignment of groups to treatments, deletion of students majoring in Aerospace Engineering, variations in section sizes, and absences on testing dates resulted in final group sizes which were slightly unequal. The first regular subtest in the course covered precision measurement, metallurgy, and general metal processing. Student scores on this subtest, titled “Common Test A”, were analyzed to demonstrate equal ability of the groups at the beginning of the study.

Design

At the beginning of the course it was announced that students would be asked to participate in an experimental study and that they would be learning subject matter reflected in the newly revised course outline while doing so. They were informed that participation in the study was voluntary and that the protocol had been approved by the University Human Subjects Review Committee. The pre-experiment announcements varied according to the intended treatments for each group. Groups A, C, and D were told that they would take a multiple-choice test which would count in their grades. Group B was given a take-home test at the time the booklets were distributed and told to return it in two weeks for a grade. Group C was given a set of study questions at the time the booklets were distributed. All other instructional units in the course were learned by students working in self-paced groups and taking subtests on the units as they studied them. The subtests were administered on three examination dates. The experimental study did not begin until after the first of the three examination dates to insure that students were comfortable in the course and knew the general procedures and expectations of the instructor. All students took “Common Test A” on this first examination date. During the class period following the first examination date, the subtests which had been taken were reviewed and instructions for participation in the experimental study were given.

Table 1
Treatments

Group	Announcement Prior to Study	Treatment 1 (Questions?)	Treatment 2 (Test?)	Delayed Retention Test?
A (*n* = 71)	"In-class test in 2 weeks"	No Study Questions	Multiple Choice Test	Yes
B (*n* = 71)	"Take-home test, due 2 wks"	No Study Questions	Take Home Test	Yes
C (*n* = 70)	"In-class test in 2 weeks"	Used Study Questions	No Initial Test Given	Yes
D (*n* = 67)	"In-class test in 2 weeks"	No Study Questions	No Initial Test Given	Yes

All students were given copies of a 34-page study packet prepared by the researcher. The packet was titled "High Technology Materials" and discussed composite materials, heat shielding materials, and nontraditional metals developed for the space exploration program and illustrated their uses in consumer products. The packet was in booklet form. It included the following resources typically found in textbooks: (a) a table of contents, (b) text (written by the researcher), (c) halftone photographs, (d) quotations from other sources, (e) diagrams and graphs, (f) numbered pages, (g) excerpts from other sources, and (h) an index with 119 entries correctly keyed to the page numbers inside. Approximately one-third of the information in the text booklet was actually reflected in the tests. The remainder of the material appeared to be equally relevant but served as a complex distracting field to prevent mere memorization of facts—the length of the booklet combined with the broad array of tables, graphs, and text precluded memorization of the entire document. Students were instructed to use the booklet as if it were a textbook and study as they normally would any class assignment.

All groups were asked to return the booklets and any take-home tests or study questions two weeks after they had been distributed. Groups A, C, and D were told to study the packet and they would be tested on the material in-class two weeks later and Group B was instructed to return the take-home tests on that date as well. On the announced test date, Group A was actually administered the initial posttest, and the take-home tests or study questions were collected from Groups B and C respectively. Groups C and D, however, were not tested initially and were told that the tests were not ready for use, so they were just lucky and would not have to take the planned test. To insure that none of these students felt cheated in terms of their grades, they were told that their highest score on any of the other six subtests would be counted double in the determination of their final grade. None of the students questioned this proposed solution to the dilemma concerning their grades excluding the proposed test on high tech materials. This was not surprising because the material in this unit was more difficult than the material in any of the units covered by the six regular subtests for the course. All booklets were also collected as previously announced.

Three weeks later (after the students had moved on to other subject matter), all groups were asked to take an unannounced delayed retention test on the same material. They were told at this time that the true objective of the experimental study was to see which type of test or study questions promoted delayed retention learning best, and that their earlier tests, if any, were not a part of the study data in any way. They were asked to do their best and told that it did not affect their grades. Participation was voluntary and all students did cooperate.

The same lab complex was used for all groups during instructional and testing periods and while directions were given. This helped to control extraneous variables due to environment. The same teachers provided all directions from prepared scripts and none administered any instruction in addition to the texts. Students were asked not to discuss the study or the text materials in any way. All class sections met for two hours on a Monday-Wednesday-Friday schedule. Half of the students in each group were in 8:00 a.m. to 10:00 a.m. sections, and the others were in 10:00 a.m. to 12:00 noon sections, so neither time of day nor day of the week should have acted as confounding variables. Normal precautions were taken to assure a good learning and testing environment.

Instrumentation

The initial test for Group A was a 20-item multiple-choice test. The items had five response alternatives. The test operated primarily at the first three levels of the cognitive domain: knowledge, comprehension, and application. The take-home test given to Group B was a parallel form of the multiple-choice test given to Group A, except that it required prose answers. The same information was reflected in both tests. The study questions given to Group C were actually the same items used on the take-home test for Group B. The only difference in these two documents was the heading.

The delayed retention test was a 30-item multiple-choice test. Twenty of the items in the delayed retention test were alternate forms of the same items used on the initial multiple-choice test for Group A. These served as a subtest of previously tested information for Groups A and B and covered the same information as the study questions used by Group C. The remaining ten items were similar in nature and difficulty to the others, but they had not appeared on either form of the initial test nor in the study questions. These were interspersed throughout the test and served as a subtest of new information.

The delayed retention test was developed and used in a previous study (Haynie, 1990a). It had been refined from an initial bank of 76 paired items and examined carefully for content validity. Cronbach's Coefficient Alpha procedure was used to establish a reliability of .74 for the delayed retention test. Item analysis detected no weak items in the delayed retention test.

Data Collection

Students were given initial instructions concerning the learning booklets and directed when to return the booklets and take the test. The multiple-choice test (Group A) was administered on the same day that the booklets were collected. Booklets, take-home tests (Group B), and study questions (Group C) were also collected on that day. The unannounced delayed retention test was administered three weeks later. Data were collected on mark-sense forms from National Computer Systems, Inc.

Data Analysis

The data were analyzed with SAS (Statistical Analysis System) software from the SAS Institute, Inc. The answer forms were scanned and data stored on floppy disk. The General Linear Models (GLM) procedure of SAS was chosen for omnibus testing rather than analysis of variance (ANOVA) because it is less affected by unequal group sizes. A simple one-way GLM analysis was chosen because the only experimental data consisted of the Delayed Retention Test means of the three groups. Follow-up comparisons were conducted via Least Significant Difference *t*-test (LSD) as implemented in SAS. Alpha was set at the $p < .05$ level for all tests of significance.

Findings

The means and standard deviations of the four groups on the “Common Test A” are shown in Table 2. Since this test was actually taken the class day before study materials were distributed and explained, a finding of $F(3,275) = 0.30$, $p < 0.826$ confirmed that the groups were of generally equal ability at the beginning of the study.

Table 2
Means, Standard Deviations, and Sample Sizes for the “Common Test A” Scores

	Metals Pretest	
Groups	**Mean**	***SD***
Group A (*n* = 71)	21.61	5.5
Group B (*n* = 71)	21.52	4.5
Group C (*n* = 70)	21.31	4.7
Group D (*n* = 67)	22.12	5.8

The means, standard deviations, and final sizes of the four groups on the Delayed Retention Test are presented in Table 3. The overall difficulty of the Delayed Retention Test can be estimated by examining the grand mean and the range of scores. The grand mean of all participants was 17.67 with a range of 6 to 27 on the 30-item test. No student scored 100% and the grand mean was close to 50%, so the test was relatively difficult. The grand mean, however, was not used in any other analysis of the data.

Table 3
Means, Standard Deviations, and Sample Sizes for Delayed Retention Test Scores

	Total Test		**Subscale A Previously Represented**		**Subscale B Novel Information**	
Treatment	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
Group A No Study Questions In-Class Test (*n* = 71)	17.48	4.5	13.11	3.1	4.37	2.0
Group B No Study Questions Take Home Test (*n* = 71)	16.62	4.4	13.54	3.4	3.08	1.7
Group C Study Questions Given No Test Given (*n* = 70)	20.07	4.1	15.13	2.9	4.94	1.8
Group D No Study Questions No Test Given Control (*n* = 67)	16.25	4.5	12.13	3.0	4.12	2.0
Overall (*n* = 279)	17.67	4.4	13.49	3.1	4.13	1.9

The GLM procedure was then used to compare the four treatment groups on the means of the Delayed Retention Test scores. A significant difference was found among the total test means: F (3, 275) = 10.60, $p < .0001$ (see Table 4). Follow-up comparisons were conducted via *t*-test (LSD) procedures in SAS. The results of the LSD comparisons on the total test scores are shown in Table 5. The critical value used was $t(275) = 1.97$, $p < .05$. The mean of the experimental group that had used the study questions, Group C, was significantly higher than all of the other experimental and control groups. The means of Groups A, B and D (Control), however, did not differ significantly from each other on the total test scores.

Table 4
Comparison of Group Means on the Total Test Via GLM Procedure

Source	***df***	**Sum of Squares**	**Mean Square**	***F***	***p*-value**
Treatments	3	618.2	206.1	10.60	<.0001
Error	275	5347.8	19.4		
Total	278	5965.9			

Table 5
Contrasts of Rank Ordered Means on the Total Test Via LSD Procedure

Group	**Treatment**	**Mean**	**Signif. Diff.***
D (control)	No Study Questions - No Test Given	16.25	C
B	No Study Questions – Take-Home Test	16.62	C
A	No Study Questions - In-Class Test	17.48	C
C	Study Questions Given - No Test Given	20.07*	A, B, D

* Groups with which means differed significantly, p < .05.

There were also significant findings in the two subscales of the delayed retention test. On the 20-item subscale of previously represented information (through a previous test or the study questions), there were significant differences: *F*(3, 275) = 10.96, *p* < .0001 (see Table 6). The LSD follow-up comparisons were made with a critical value of *t*(275) = 1.97, *p* < .05. These results are shown in Table 7. Group C (study questions) outscored the other groups and Group B (take-home test) also outscored the control Group D.

Table 6
Comparison of Group Means on the Subscale of Previously Represented Information Via GLM

Source	***df***	**Sum of Squares**	**Mean Square**	***F***	***p*-value**
Treatments	3	321.3	107.1	10.96	<.0001
Error	275	2686.4	9.8		
Total	278	3007.7			

Table 7
Contrasts of Rank Ordered Means on the Subscale of Previously Represented Information Via LSD Procedure

Group	Treatment	Mean	Signif. Diff.*
D (control)	No Study Questions - No Test Given	12.13	B, C
A	No Study Questions - In-Class Test	13.11	C
B	No Study Questions – Take-Home Test	13.54	C, D
C	Study Questions Given - No Test Given	15.13*	A, B, D

* Groups with which means differed significantly, p < .05.

Results were more complicated in the subscale on material that was not previously represented. The GLM finding on this subscale was $F(3, 275) = 11.80, p < .0001$ (see Table 8).

Table 8
Comparison of Group Means on the Subscale of Novel Information Via GLM Procedure

Source	*df*	Sum of Squares	Mean Square	*F*	*p*-value
Treatments	3	127.8	42.6	11.80	<.0001
Error	275	992.8	3.6		
Total	278	1120.6			

The results, with a finding of $t(275) = 1.96, p < .05$, are shown in Table 9. The take-home test group (Group B) scored significantly lower on this subtest than any other group. One would expect that the group which used the study questions (Group C) should score about the same as Group B because they had essentially the same treatment—recall that the study questions were the exact same document as the take-home test except for the title and heading directions. This, however, was not found; the take-home test group scored lowest on this subtest and the group with the study questions scored the highest of all groups.

Table 9
Contrasts of Rank Ordered Means on the Subscale of Novel Information Via LSD Procedure

Group	Treatment	Mean	Signif. Diff.*
B	No Study Questions – Take-Home Test	3.08*	A, C, D
D (control)	No Study Questions - No Test Given	4.12	B, C
A	No Study Questions - In-Class Test	4.37	B
C	Study Questions Given - No Test Given	4.94	B, D

* Groups with which means differed significantly, p < .05.

Discussion

Three research questions were addressed by this study:

1. *If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning?* A very consistent finding of several previous studies has been that all tested groups have outscored those who did not take an initial test regardless of the form of the test (Haynie 1990a, 1990b, 1991, 1994, 1995a, 1997b; Nungester & Duchastel, 1982). In the present study, this effect could not be clearly demonstrated with significant findings, however, there was a non-significant trend which was generally in harmony with the findings of the previous studies.

2. *Do students study and prepare differently depending on the type of test they expect to take?* Within the constraints of this study, it appears that they do. Since the students who experienced the take-home test significantly outscored the control group on the subtest of previously represented information (on which they had the second highest ranked mean) but performed the worst of all groups on the subtest of novel information, it appears that they used the take-home test document as a “road map” and hunted only for the exact information needed to answer the specific questions on the take-home test. Other groups, even the control group, must have studied more broadly in the conventional manner expected. It appears that the take-home test group skillfully used the table of contents and index of the booklet to seek out the specific answers required on the take-home test, and they may not have read the entire booklet. The fact that the group with the study questions (which were the same questions as those on the take-home test) scored higher on this subtest appears to indicate that they did read and study the entire booklet and merely referred to the study questions for additional indicators of the intended goals of the instructor.

3. *Can the effects of differing study methods be detected in delayed retention tests?* If the conclusion posed above is correct, then it would seem that this study has succeeded in detecting differing study methods among these students. It seems that all of the groups, except for the take-home test group, likely read and studied the booklet in a broad manner while the take-home test group simply hunted for the required answers. The conclusion here is that, in general, students do likely study more fully when they expect an in-class test than when they are given a take-home test.

Recommendations

Since testing consumes such a large amount of teacher and student time in schools, it is important to learn as much as possible about the effects of tests on learning. It is important to maximize every aspect of the learning and evaluation process. The ability of teachers to develop and use tests effectively has been called into question recently; however, most research on testing has dealt with standardized tests. The whole process of producing, using, and evaluating classroom tests is in need of further research. This study was limited to one educational setting. It used learning materials and tests designed to teach and evaluate a limited number of specified objectives concerning one body of subject matter. The sample used in this study may have been unique for unknown reasons. Studies similar in design which use different materials and are conducted with different populations will be needed to achieve more definite answers to these research questions. However, on the basis of this one study, it is recommended that:

If an instructor wishes to use a take-home test, and the goal is a high level of retention learning, the instructor should be very careful to design the take-home test so that the required responses will include all of the important information that the students should learn.

1. When useful for evaluation purposes, classroom testing should continue to be employed due to its positive effect on retention learning,
2. Students should know in advance how they will be tested because of the effect this information may have on their study habits, and
3. Aids to independent learning in the form of study questions appear to enhance retention learning without tempting students to take a lackadaisical approach as they may do with a take-home test.

The time devoted by teachers and students to classroom testing apparently does have learning value in addition to its utility for evaluation purposes. The value of tests in promoting retention learning has been demonstrated here, and research questions about anticipation of tests and the effects of take-home tests have been addressed; however, there remain many more potential questions about classroom testing. Further research is needed to help teachers maximize the learning benefits of tests.

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Use and Documentation of Electronic Information: A Survey of Eastern Regional Technology Education Collegiate Association Students

by Hassan Ndahi

Introduction

Computer technology is rapidly changing how students access and disseminate information. The idea that technology will make information quickly available to the individual goes back to the early days of the computer, which began with punch-card technology in 1890 and continues with the use of integrated circuits and the revolution of the personal computer in the late 1970s (Stephenson, 2002). Since the beginning of the microcomputer revolution, the dream of information retrieval has become a reality. It would have been difficult to guess 50 years ago that pictures and words could be sent and viewed instantaneously at a remote site at the whim of the user. Yet this is what the Internet provides. It is not a technology for selected individuals or professions, but for everybody, all occupations and all age groups. The importance of the Internet and World Wide Web cannot be overemphasized because of the innumerable ways that it can be used for educational purposes. One very important way that this technology is serving the scientific community is through research and communication (Brody, 1996). Library resources from universities across the country and the world can be accessed through the Web (Francis, 1997), a capability of great importance to instructors, researchers, and students everywhere. Today, information that can benefit students is available in virtually all fields of study, but only if they can use the technology well. Certainly, there are students who do not use it to its full capacity due to lack of knowledge of its capability or of how to use it.

The Problem

Although it is easy to assume that students who study engineering or other technological areas will adjust quickly to using the Internet and use it well, this assumption may not be true. Using electronic resources is a new way of accessing information and must be considered a change in education that demands a new approach to some aspects of students' learning. While the Internet can be helpful to students in terms of accessing information for research and assignments, there is a strong possibility of plagiarism (Auer & Krupar,

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2001; Scanlon & Newman, 2002). For example, students who know in advance that they will find a suitable paper to download, or those who panic because they have waited too long before starting an assignment may take the easy way by downloading papers from the Web (Renard, 2000). Similarly, there are businesses that sell compositions written by successful applicants, claiming that selling successful papers merely helps disadvantaged students and does not encourage plagiarism (McCollum, 1997). Instructors and admissions counselors are worried about students' sharing term papers or copying papers posted on the Web (McCollum, 1996, 1997). If an assignment is to achieve its purpose and proper learning is to take place, such activities should be of real concern to instructors.

Purpose and Research Questions

The last five years have seen widespread use of the Internet in educational institutions as a means to strengthen research and learning. Because information and documents are reproduced and circulated electronically, students can access information for research and assignments without using print material. However, if students are to use non-print materials effectively, they must be able to search for information successfully and also be able to document or annotate their sources. The purpose of this study was to gain information from students as to how they use the Internet, whether they understand and document electronic information, and whether or not their instructors question Internet information that is not documented.

To achieve the purpose of this study, the following questions will be answered:

1. Are technology education students aware of the importance of the Internet?
2. Do technology education students use the Internet for educational purposes?
3. Do technology education students properly document information obtained from the Internet?
4. Do technology education instructors question work that is not properly documented by students?

Method

This study uses a descriptive research approach to obtain information concerning students' use and documentation of electronic information. The design for the study was the One-Short Case Study, because a single group of student conference-attendees was studied once, subsequent to their use of the Internet (Campbell & Stanley, 1963).

A survey instrument was developed specifically for this study. Some items on the survey were taken from two instruments: the use of computers for workforce development (Ndahi & Gupta, 2000) and meeting the digital literacy needs of a growing workforce (Gupta & Ndahi, 2002). Questions were modified to suit the purpose of this study. A 4-point Likert-type scale was used for determining the level of agreement or disagreement with statements, with 1 = Strongly Agree, 2 = Agree, 3 = Disagree, and 4 = Strongly Disagree. Additional open-ended questions elicited further opinions.

The instrument was evaluated for face and content validity by a panel of experts made up of four instructors who teach computer courses and are experienced in research. The panel reviewed the questions on the instrument to determine if they accurately sought information to answer the research questions. After the panel's review, the survey was pilot tested with a group of 10 students who answered all the questions and also identified any question or statement that was misleading. Overall, the instructions and questions were clear to the students.

The population for this study was selected from technology education students attending the 2002 Technology Education Collegiate Association's (TECA) Eastern Regional Conference in Virginia Beach, Virginia. The institutions represented at the conference were Central Connecticut University, Georgia Southern University, Clemson University, Fairmont State College, The College of New Jersey, Old Dominion University, Virginia Polytechnic Institute and State University, North Carolina A&T University, Virginia State University, Millersville University, and California University of Pennsylvania. Approximately 220 students attended the conference. The procedure for selecting subjects for the study was the purposive sampling method (Borg & Gall, 1989). Students were approached by volunteer students administering the surveys during the awards luncheon and asked if they would participate. Only students who agreed were given a survey to complete. A total of 156 surveys were distributed and 130 were collected, representing an 83.3% return. Two questionnaires were not complete and therefore not analyzed.

Data Analysis

The quantitative data were analyzed using frequencies and percentages. The data from the open-ended questions were sorted and assigned to categories relevant to the investigation (Stainback & Stainback, 1988): the importance of the Internet, utilization of the Internet, documentation of information, and instructor responsibilities. Frequencies and percentages were also used to further explain data from the open-ended questions.

Importance and Utilization of the Internet

Students responded to several questions related to the importance of the Internet and how they use it. Ninety-three percent of the students agreed or strongly agreed that the Internet is an important technological tool for finding information and for research, while 7% of the students disagreed or strongly disagreed with the statement. In responding to the statement about how they learned to use the Internet, a large majority of the students (91.4%) agreed or strongly agreed that they learned by "trial and error." The students were asked if they had learned the Internet in some of their classes. The majority (72.7%)

disagreed or strongly disagreed. Table 1 reports the responses to these statements.

Table 1
Importance and Utilization of the Internet

	Agree/ Strongly Agree		Disagree/ Strongly Disagree	
Item	*n*	%	*n*	%
The Internet is an important tool for information and research	119	93.0	9	7.0
I learned to use the Internet by trial and error method	117	91.4	11	8.6
I was taught how to use the Internet to search for information in some of my classes	35	27.3	93	72.7

In response to the question as to how long they had been using the Internet, 21 (16.4%) of the students said for about 6 years, while all others had been using it between 2 and 5 years. Only 14 students (10.9%) had taken a course or had formal training in classes such as computer science, computer basics, computer literacy, and technical writing. The overwhelming number of students, 89.1% (*n* = 114), had not completed a course or any formal training on how to search for information.

When students were asked to list Web sites and search engines they used to get information for research or assignments, 32% (*n* = 41) said they use Yahoo, and 29% of the respondents (*n* = 37) said they use Google. Other search engines used by students were Lycos, Hotbot, Infoseek, Altavista, AOL, AskJeeves, MSN, and Netscape. No Web sites were listed as sources for information.

Students were asked to list courses for which they were able to search for information from the Internet to complete an assignment. The courses listed by most students (95.3%) were English, Psychology, Geography, History, Communications, Transportation, and Basic Concepts of Computers. Other subjects that were listed by not more than three students were Manufacturing, Energy and Power, Industrial Design, Graphic Communication, and Electronics.

Respondents were asked their opinion about the best way to learn to use the Internet to search for educational information. Forty-nine students believed that trial and error is still best. Others suggested that it is through assignments, taking a course in computer literacy, and using instructors' guides. Many students believed that a computer literacy course should be a general education requirement, as is the case in some institutions.

Although nearly all students (93%) recognized the importance of the Internet as a technological tool for research, only 17.2% said they used it for that purpose. Seventy percent indicated that they used the Internet mainly for electronic mail (e-mail), while 13.3% used the Internet for fun, games, accessing music, shopping, visiting "adult sites," and searching for employment opportunities. In the words of one student, "I use the internet for e-mail, price comparison, and music." Students were asked if it were easy for them to do most of their assignments because of the availability of information on the Internet. Seventy-eight students (60.9%) agreed or strongly agreed with this statement because similar information or assignments are available online.

Information Documentation

Students can obtain information instantly with the click of the mouse. However, some were not aware that they had to document this information. A large majority (78.9%) disagreed or strongly disagreed that they were aware that it was necessary. Eighty-five students (66.4%) agreed or strongly agreed that it was difficult to document information obtained from the Internet. Ninety-five students (74.2%) agreed or strongly agreed that the Internet information is for the public and therefore does not require documentation. A significant majority (79.7%) agreed or strongly agreed that only information that is copyrighted needs to be documented. Table 2 presents the responses to these statements.

Table 2
Information Documentation

	Agree/ Strongly Agree		Disagree/ Strongly Disagree	
Item	*n*	%	*n*	%
I am aware that it is necessary for me to document the sources of information obtained from the Internet	27	21.1	101	78.9
It is often difficult to document electronic information	85	66.4	43	33.6
Electronic information does not require documentation	95	74.2	33	25.8
Only copyrighted information should be documented	102	79.9	25	19.5

Instructor Responsibilities

The role of instructors in contributing to students' documenting their work is important. A majority of the students (64.8%) disagreed or strongly disagreed that their instructors taught them how to annotate or document information from the Internet. Likewise, a majority (69.5%) agreed or strongly agreed that their instructors were more interested in the completion of their assignment and less concerned about the sources of the information. Table 3 reports this data.

Table 3
Instructor Responsibilities

	Agree/ Strongly Agree		Disagree/ Strongly Disagree	
Item	*n*	%	*n*	%
My instructors taught me how to document electronic information	45	35.2	83	64.8
My instructors are only interested in the completion of an assignment, and not the source of information	89	69.5	39	30.5

Results

The population for the study was delimited to the students who attended the Eastern Regional Technology Education Collegiate Association Conference in 2002. As such, the results should not be generalized to all technology teacher education students. However, the results of this study can serve as a reference point for studying a much larger population. They could also serve as a basis for looking at other issues relevant to this study.

The Importance of the Internet and Utilization

Almost all students concurred that the Internet is an important technological innovation. It is significant that all students used the Internet, though it was used for a variety of purposes. An overwhelming number of students had not had any formal training on how to use the Internet to search for information. They learned to use it by trial and error. The students were familiar with different search engines, but provided no evidence that they were familiar with specific Web sites that are relevant to their areas of study. Nonetheless, the Internet is helpful, according to more than half the respondents, when it comes to completing assignments. A majority of the students said it was easy for them to do their assignments because they could find similar ones on the Internet.

Information Documentation

It is important to know whether students are aware of the need to document electronic information just as they do information taken from print material to avoid plagiarism. More than three-quarters of the students indicated that they were not aware of this. While some believed that electronic information required documentation, others thought that applied only to copyrighted information. Two-thirds of the students indicated that it is difficult to document electronic information.

Instructor Responsibilities

Instructors certainly have an obligation to teach their students how to document sources of electronic information and to question Internet information that they do not document. However, only about a third of the students indicated that they had been taught annotation procedures. Additionally, the majority of the respondents supported the statement that their instructors were not interested in the sources of their information, but only in the completion of the assignment.

Discussion

The Internet is among the most significant innovations of the Twentieth Century. The technology is used for personal, professional, and educational purposes. It enables e-mail communication, posting questions to instructors, receiving and delivering assignments, research, and participation in listservs (Perrin, 1997). As a user-friendly technology, it is a valuable teaching resource for instructors and learning resource for students.

It is evident from this study that the students acknowledge the usefulness of the Internet. However, their perspectives vary regarding how effectively they use it. Only 14 students had formal training in how to use the Internet to search for information. Most of the students learned to use the technology by themselves or were introduced to it by their friends. This might be one reason why the majority of the participants said they used it only for e-mail, and only a small proportion used it for research.

Regardless of how user-friendly the Internet is, students may use the technology more effectively only if they receive formal training (Scherer, 1997). This can be achieved in many ways. Some of the students suggested that pertinent courses should be required as a regular part of their plan of study. Some said they would prefer that their instructors teach them how to access information that is specifically relevant to the courses they teach. This, in fact, may be the only way in which students can become familiar with available resources.

There are numerous Web sites sponsored by organizations, associations, journals, and magazines that serve teachers and students of technology education. However, no student mentioned any of these sites. Instructors need to be aware of online and Internet resources available for their students (Flowers, 2001). If students are to use online resources effectively, instructors must take some responsibility for introducing them to their students. It is, therefore, not a surprise that students were not aware of these important Web sites.

As with their counterparts in other studies (see Renard, 2000), students in this study were clearly aware of how easily information can be cut and pasted from the Web into assignments or term papers. Yet the vast majority were not aware that the sources of the information they copied from the Web had to be documented to avoid plagiarism. The students somehow saw information taken from the Web to be different from information printed on paper in traditional books and periodicals. This shows total ignorance on the part of a significant number of students who participated in the study. Internet plagiarism apparently continues to be a concern for instructors, just as it has in the past (see McCollum, 1996). In addition to the issue of plagiarism is the fact that the educational and learning value of assignments that are completed simply through cut and paste operations is lost.

Should students take complete responsibility for their ignorance? Given these findings, it seems less than fair to hold them totally accountable for failing to properly cite references. Students are apparently not taught about the importance of citing information sources. Moreover, they perceive that instructors are not particularly concerned about where the information was obtained or whether it was cited properly. Instructors, therefore, may actually be contributing to the spread of plagiarism by oversight, and or low expectations (see Freedman, 1998). Perhaps it is not only the students who are struggling with electronic information technology, but the instructors as well.

The problem of documenting electronic information should be viewed as a significant opportunity for change in education (McDowell, 2002). Some may argue that this situation reveals the shortcomings of high school curricula and implies a need for revision of freshman-level college courses. Such blame-passing, though, is likely to be unproductive. Instead, instructors must restructure their assignments so that in situations where students use Web resources, they are required to document their sources of information (Carnevale, 1999; Drogemuller, 1997). Certainly the Internet has made a great impact on education, and as we educate our students for their computer-dominated future, instructors must address the growing opportunities for dishonest use of the technology (Reanard, 2000). Taking a second look at our curriculum may be one of many ways to solve the problem of electronic information documentation and plagiarism.

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Basic Principles in Holistic Technology Education

Kurt Seemann

Introduction

A school that adopts a curriculum, that aims for a holistic understanding of technology, does so because it produces a better educated person than a curriculum which does not. How do we know when we are teaching technology holistically and why must we do so? Increasingly, more is asked of technology educators to be holistic in the understanding conveyed to learners of technology itself in order to make better informed technical and design decisions in a wider range of applied settings. The ability of the learner to naturally consider social and environmental factors, for example, when seeking solutions is seen by some State education systems in Australia as fundamental to a genuine education in technology (New South Wales Board of Studies, 2000 & 2002). In philosophy, the holist position asserts that to understand the particular one must understand its relation to the whole and that only through reflection of one's sensation based applications can genuine knowledge be critically affirmed (Matthews, 1980, p.87 & p.93). The combined apparently independent paths of the State and the Holist positions set a compelling scene not only for the socio-economic necessity for holistic technology education in the curriculum but also for Technology's status as a key curriculum agent in the knowledge formation process of educated individuals.

This paper asserts that the general elements of Applied Setting (including Time), Human (as Agent), Tool and Environment are well placed to be the necessary basics to any holistic human technological activity. How and why these elements work together, their schema, will be referred to in this paper as the 'Basic Principles'. The paper presents the thesis that Technology cannot be reduced to less than these general elements and as such, Technology is their product. We therefore may need to understand and teach these elements and their relations to each other explicitly, in ways that reveal the utility of such understanding when making technical choices and design decisions for all the genres of technology and at all their scales of application and discovery. The case is made for technology to not merely be a 'know how' learning experience, but necessarily also a holistic 'know why' learning experience essential for developing and transferring technological knowledge.

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The notions of holistic education are in themselves not new. Work on the importance of holistic education dates back in Western settings at least to Pestalozzi (1746-1827), Thoreau (1817-1862), Emerson (1803-1882), Alcott (1799-1888), Dewey (1859-1952), Steiner (1861-1925), and Montessori (1870-1952); and more recently to Hill & Smith (1998), Dufty, Dufty, Australian Curriculum Studies Association, & Holistic Education Network (1994), and Fowlers (1998).

However, what is relatively new in Australia is that expressions such as "holistic solutions" are entering new draft *Design and Technology* secondary school syllabi (New South Wales Board of Studies, 2002). There is a need to understand technology *itself* holistically in order to teach it with greater knowledge structure for learners. Redressing foundations for understanding technology itself is overdue in our rapidly changing societies and economies. While such general commentary has been recently entertained (Lewis, 2000; Petrina, 1998), this paper seeks to examine the basis for a holistic understanding of technology specifically, and thus the curriculum, teaching, and learning implications that may flow from such understanding. It is timely to examine useful schemas for how educational curriculum and pedagogy may be structured to assure that learning in technology is indeed holistic in presentation, assessment, and reporting. What is needed is a robust universal schema.

In addition to new school systems requiring students to learn technology holistically, there are emerging signs that such understanding is also becoming a vocational attribute expected of employees. Just as reporting is a motivator for what schools will focus on in the delivery of their courses, so too is it an emerging expectation for corporations and organizations to report on "The Triple Bottom Line": profit/loss, social and environmental balance sheets of effort, and expenditure (Elkington, 1997; Wand, 2002). A desired capability is for employees to naturally be disposed to include social and environmental decision factors in their contribution to enterprise and production. In order for both students and employees to display holistic capabilities, this paper asserts that they ought first develop holistic understanding and holistic knowledge as a framework for guiding development of any associated capabilities in technology practice.

A Schema for Establishing a Holistic Understanding and Knowledge of Technology

There can be many approaches to understanding the phenomenon we label *technology*. Presented here is a phenomenological view to offer the reader a deeper grounding into why certain conclusions are drawn and schemas proposed. A schema gives teachers a framework to evaluate just how holistic a lesson or curriculum is and can help a teacher decide what educational tasks to include and how to construct the educational context and experience that will foster holistic understanding in technology and design.

We begin with the premise that holistic technology education is a necessary, rather than desirable, outcome of schooling. The classical holist position in education may be illustrated as follows:

> To know things is to know things in relation; to know a part is to know how it connects with the whole. In the process of codification, different impressions of the same object or process are utilized so that interrelations might be recognized. It is the total vision which we call knowledge. (Matthews, 1980, p.93)

Many teachers would argue that they already teach technology holistically. However, the question we must pose is, how do we know?

Question 1: How do we know we are teaching technologies holistically?

There are many responses teachers give to this question. Typically, they may range from "because my students discuss many issues in the design process" to "I make sure they engage in social and environmental perspectives." The problem with such responses is that what is holistic is not grounded in some universal reason or coherent schema of dependent relations. Why should discussing social and/or environmental issues be included for claims of holistic technological learning? Can one choose to discuss these elements, or must one connect the dependencies of these elements to the technology being learned? Such musings can quickly frustrate teachers, who often conclude that to teach holistically, one needs to teach and consider everything. At this point some teachers may be lost. Very often, at this point, some teachers find the task to revert to traditional "particulars" like tool skills and task technique is all they can do. That is, they revert to their narrow, but comfortable zones of assessing tools and technique skills and particular knowledge for a product so that the student can take home the object as a sign of successful learning. This paper suggests that such patterns of pedagogy should be redressed.

Phenomenology of technology and knowledge development allows a teacher to use a *basic principles* approach to formulate a universal schema or cognitive framework. With basic principles, a teacher can indeed determine what to include in lessons and evaluations to ensure reasonable holistic coverage of any technical education. Surprisingly, we discover that technology education and practice are not only a *how-to* experience, but significantly a *know-why* experience. The latter is fundamental to the human act of *creatin*g new knowledge itself, not just *using* knowledge. *Know-why* capability is important for principles development. It fosters the reason *why* for things in many settings, accommodating both the benefit of situational learning while also enabling learning transfer or innovation to occur. Holistic education in technology enables transfer of understanding to novel lifelong encounters, a quality lacking in much of *how-to* training in technology particulars.

Knowing and Understanding Through Practical Engagement in Technological Learning

The schema developed here begins with foundations in understanding how technical or material experience, as a phenomenon in human activity, develops a socially defined view of what knowledge is. When can we claim we know something? Dialectics and praxis are very useful reasoning tools for understanding the nature of an answer to this question in the context of technology education. Why is this important? This section of the paper presents the case that "knowing" and especially "understanding" occur better through holistic educational experiences in technology, if structured properly, compared to other modular, decontextualized, or disintegrated task skill approaches. It is significant in our construction to recognize that theory and practice dichotomies, as currently presented in many secondary and tertiary schools in technology, are a problem. "Theory is taught through practice, and good practice is grounded in good theory," as my education lecturer often drilled. We do not really want to present technology education as separating *conceptual tool* experience (how to think skills) from *physical tool* experience (how to do skills). We do not want to see "theory" classes estranged from "practical" classes, nor theory devalued or even employed as punishment in learning technology and design. It is not the product or the technical process we assess as educators, but the learner and his learning.

Tool is defined here as anything we give use-value to as an instrument. A brick or our fist is a tool if we decide to use it as a club. A car is a tool if we decide to use it as a means to get us from A to B. An engineering algorithm is a tool if we decide to use it to determine a load on a beam. In each case, tools help us do things normally to manipulate a *material,* whether that material is at a scale we relate to in ordinary experience or extraordinary, like information/data that we manipulate with an algorithm or *virtual tool.*

Curricula and pedagogy that normally segregate knowing and doing raise substantial educational concern and have so for many years. For Dewey,

> A divided world, a world whose parts and aspects do not hang together, is at once a sign and a cause of a divided personality. When the splitting up reaches a certain point we call the person insane. A fully integrated personality, on the other hand, exists only when successive experiences are integrated with one another. It can be built up only as a world of related objects is constructed. (1963, p.44)

Dewey was quite strong on this issue. We need to show how things are interconnected as necessary interdependencies to give the technology or technique meaning to students. This highlights the importance of holistic education. A segregated education for Dewey was not an education:

> On the intellectual side, the separation of 'mind' from direct occupation with things throws emphasis on things at the expense of relations or connections . . . [Education] must find universal and not specialised application. (1966, p.143)

Dewey's work clearly opens one of the differences between technology *education* and technical *training*. the latter being geared to vocational, specialized short-term task skills; the former, lifelong human capability. Our interest is in technology education that shows us the *basic principles* for teaching technology holistically: the interconnectedness or dependencies of technologies. Our next question may therefore be:

Question 2: What exactly should be interconnected in our teaching of technology?

The following formulates a case to answer this question. We will build the basic principles of what the minimums are for a holistic technological experience, ideally expressed in universal terms to permit knowledge transfer in teaching and learning for any genre of technology curriculum. The learner needs to become capable in technology and design matters and acquire lifelong principles.

From Dialectics to Praxis in Technology Education: Building Understanding and Knowledge

The road from dialectics to praxis is an interesting one for technology educationists because it addresses twists and turns (even head flips) from knowing as an essentially theoretical (idealistic) process to a social-material (surprisingly design- and technology-like) process. We will begin with Hegel (1770-1831), who was a German idealist philosopher born in Stuttgart. He was an idealist because for him, thought does not merely correspond to reality; it produces reality (Speake, 1979): our thoughts *are* our reality and so all knowledge can be formulated through pure reason. "Dialectic" was Hegel's name for the pattern that logical thought must follow. Broadly, he argued that conscious thought proceeds by way of contradictions. Its process is by triads, where each triad consists of thesis, antithesis, and synthesis. The concept of "sharp" is not adequately understood without reference to an alternative "blunt." Both the thesis concept of sharp and the antithesis concept of blunt define each other and therefore require each other. To see each concept as related, as mutually defining, is their synthesis. At this moment a new level of *reasoned understanding* is achieved. Put another way, a person starts with a proposition, the thesis; this is consciousness as "understanding" and proves to be inadequate by itself. The person's mind must therefore generate its alternative, the antithesis. However, this on its own also proves inadequate. The resolution of the opposites, therefore, requires that they be combined into a synthesis. This is the level of conscious thought, or *reasoned understanding*. From here, the whole triadic process may be repeated, the synthesis leading to a new thesis, and so on.

This is elaborated in Hegel's *Phenomenology of Mind* (1807) (Vazquez, 1977, p.371).

The essence of Hegel's dialectics is "the grasping of opposites in their unity" (Hegel & Miller, 1989), a significant first step in building our *basic principles* for holistic technology education. This is the immanent goal or "telos" of Hegel's philosophy. In the words of Suchting:

> So, in Hegel, Spirit is essentially rational freedom and the source of the dialectical development; the conflict between the necessity for Spirit to attain its telos and the various successive inadequate conditions for this to occur . . . insofar as the system has an immanent telos the development envisaged is one towards reconciliation of conflicts in a larger harmony, hence, the Hegelian dialectics is conservative in its very foundations and not merely as a consequence of certain historical and personal factors. (1983, p.181)

Important to Hegel's philosophy of dialectics is that "knowing" for him begins, proceeds, and ends at the level of ideas. For him, matter is a product of mind, rather than mind being the highest product of matter. All our knowledge comes from pure theoretical reasoning.

Feuerbach and Hegelian Dialectics: The Head Flip

Feuerbach (1804-72) was a Bavarian philosopher and theologian. Although he was Hegel's student, much of his work was critical of Hegel's idealism. Generally, Feuerbach was a *materialist* in the sense that he distinguished between consciousness of an object and self- consciousness. At the same time, he connected the material object with the subject by pointing out that consciousness of the object always reveals some element of self-consciousness: "In the object which he contemplates, man becomes acquainted with himself, consciousness of the objective is the self-consciousness of man" (Vazquez, 1977, p.75).

Feuerbach is important because his view of knowing and understanding introduced material objects (the world or environment outside the reasoning mind) as a necessary, not merely desirable, condition for knowledge. This revelation further builds our *basic principles* for holistic technology education. Experiences from the environment outside the mind are now significant. For Feuerbach, humans are sensual beings, not theoretical beings, as in the Hegelian sense:

> I unconditionally repudiate absolute, immaterial, self-sufficing speculation, that speculation which draws its material from within. . . . I found my ideas on materials, which can be appropriated only through the activity of the senses. I do not generate the object from the thought, but the thought from the object. (1843)

It is often said that Feuerbach inverts Hegel, turns him on his head. For Feuerbach, mind now becomes the highest product of matter rather than matter being a product of mind. All our knowledge comes from pure material experience.

Marx on Hegel's Idealism and Feuerbach's Materialism: Resolving the Theory-practice Opposing Views of Knowledge.

Marx (1818-83) was regarded by some as more of a social theorist, interested mainly in economics and history than in any particular philosophical doctrine. Essentially Marx, too, inverts Hegel's idealism. He extracted and supported Hegel's notion of dialectics, but rejected his idealist approach. He supported Feuerbach's inversion of Hegel, but differed from his concept of materialism in terms of the central notion of human practice, specifically the social dimension of practice.

Marx rejected Feuerbach's relation between subject (the person) and object (the environment) in which the subject is passive and contemplative, restricting himself to receiving or reflecting reality. Here, knowledge was simply the result of the actions of objects in the external world and their effects upon the sense organs (Vazquez, 1977, p.118). Marx, therefore, identified the strengths and weaknesses of Hegel's idealism in dialectics and Feuerbach's passivity in materialism.

Marx attempted to resolve the problems of idealism and materialism in his system of *historical materialism*, the central concept of which focuses on the *practical interaction, which must occur between a person and his/her material and social environment*. In parallel with Hegel's dialectics, the synthesis of people and their environment, via practical human *socially contextualized* activity, meant that a new level of awareness was achieved. Both the person and the environment were transformed (Vasquez, 1977, p.193).

It is significant to divert slightly at this point to bring in a key notion that centres the importance of technology learning to a society. Not only is technology a study for its obvious applied and economic value, but there is a case that technological learning, if connecting the general elements of human (as agent), tools, and materials (as environment) to an applied setting, is a necessary feature of knowledge formation and discovery:

> . . . there is no such thing as genuine knowledge and fruitful understanding except as the offspring of doing . . . Men [sic] have to do something to the things when they wish to find out something . . . The laboratory is a discovery of the condition under which [human] labor may become intellectually fruitful and not merely externally productive. (Dewey, 1966, p.275)

Technology is not the slave of science nor the neutral tools in designing. Rather, technology is one of their full and equally rich symbionts and plays an active role in knowledge formation!

In *Question 1*, the paper initiated the quest for the need to learn technology holistically. In *Question 2*, the essential interconnected elements were explored for what may constitute the holistic foundations of technological understanding.

To progress to the final stage in this paper, there is a need to establish both the structure and nature of such a holistic understanding of technology that permits its status as a study area that is both essential to knowledge development and to application. The integrating notion of praxis is proposed as a useful mental tool to address the final step of synthesizing how the elements of human (as agent), tools, and environment, applied over time, work together.

Praxis and Technics: Arriving at our Basic Principles of Holistic Technology Education

Question 3: How do the applied setting, human, environment, and tool elements combine holistically so that a person comes to know something of the world?

Marx departed from Hegel and Feuerbach by the importance he places on actual human labor or practice. He adopted a dialectic methodology in that he contrasts and identifies the inadequacy of "pure" idealism and "pure" materialism; he synthesized the two at the new level of historical materialism. This introduces the importance of time. The applied setting is subject to evolutionary influences. Both theory and practice in the applied setting are resolved best, according to Marx, via human *material* practice in social and historical context. Marx's thesis of historical materialism is essentially the foundation of praxis. Praxis and technical activity concern the effect of instruments and tools in the human transformation experience. The contributions of Don lhde (1979) on instrumentation are summarized as key notions to a schema for constructing *basic principles* in holistic technology and design education.

Praxis, so far has been concerned with practical human activity and the interaction of mind and matter, or human and environment. Ihde's work identifies certain features of this interaction when instruments or artifacts modify it. The human-environment interaction becomes a more complex paradigm when an artifact modifies the experience:

Human (Agent)---------- World (Environment)
is modified to:
Human (Agent) --------- Artifact (Tool) -------- World (Environment)
Examples may include:
Observer ----------- Microscope ---------- Microbe
Student-----------Internet Computer--------World Information

The observer does not gain feedback from the world anymore, but from the world via the instrument or tool. That is, tools and so technologies are values that are rich in their design, use, and context, and are active in their cause and effect tendency. However, lhde pointed out that this modified interaction, although non- neutral, is not necessarily a problem:

> My thesis is that any use of technology is non-neutral. However, non-neutrality is not a prejudicial term because it implies neither that there are inherently 'good' or 'bad' tendencies so much as it implies that there are types of transformation of human experience in the use of technology. (1979, p.66)

Ihde acknowledged that technologies need to be understood in context and in purpose of application. That is, different kinds of technologies and tools transform our knowledge differently. Also, the same tools and technologies placed in different "world" settings transform our knowledge differently, including the same tools/technologies in different social and/or material environment settings, that is, different world settings.

This is significant because it raises the necessity for understanding that both choice and design of tools and choice and design of world settings alter our knowledge. Technologies are context sensitive— a key notion in technology choice, transfer, and innovation diffusion. Designs of tools and environments are socially and environmentally interdependent. To present technology teaching and learning as value- and context-neutral is to misinform the learner. The ability of the learner to naturally consider social and environmental factors when seeking solutions to design and technical challenges is fundamental to a genuine education in technology. Human, *tool,* and environment in an applied setting are the minimum elements of any technological activity. Each element is a resource and constraint, and each require the other to define their value in the applied setting. The elements are interdependent. Technology cannot be reduced to less than these general elements and as such, technology is their product. We therefore may need to understand and teach these elements and their dependent relationship explicitly.

What develops as important in lhde's work is the notion that praxis, though necessarily producing artifacts from the human-environment interaction, must increasingly include artifacts as a mediator in the interaction. Hence, the paradigm in Figure 1 shows how each of the elements, while having an identity (a "lobe"), also shares a necessary mutual dependency with the other elements via the applied setting:

We now have a basis for determining the absolute minimums of what constitutes holistic technology education (Seemann & Talbot, 1995). To teach any technical process, to evaluate technologies, or to make design decisions that ignore this *interdependent* schema of human, artifact/tool, and environment is indeed not an education in technology. In the theme of Dewey (1963), the interconnectedness of knowledge constitutes a key feature of an education.

> Any experience is mis-educative that has the effect of arresting or distorting the growth of further experience . . . Experiences may be so disconnected from one another that, while each is agreeable or even exciting in itself, they are not linked cumulatively to one another . . . Each experience may be lively, vivid and 'interesting', and yet their disconnected-ness may artificially generate dispersive, disintegrated, centrifugal habits. The consequence of formation of such habits is inability to control future experience. (p.49)

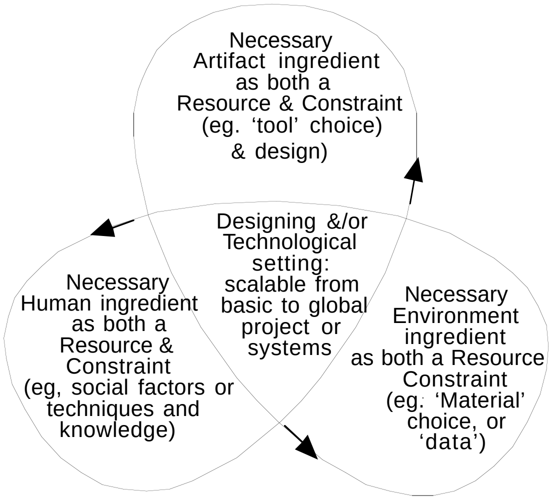

Figure 1. Minimum elements and their dependencies to teach in and about any applied design and/or technology setting.

The *basic principles of holistic technology education* now appear to have structure, a structure articulated elsewhere as *technacy* education (Seemann & Talbot, 1995). When teachers instinctively claim that they include social (human) factors, technical (tool) factors, and environmental (material) factors in their lessons for specific applied settings, they indeed have good reason to believe their pedagogy is heading toward being holistic. However, this coverage cannot be delivered in a general way. It is important to present the interconnections in explicit detail highlighting necessary and specific dependencies that make sense. A key requirement is to set learning experiences and assessment tasks for each lesson and unit of work that not only address highly specific links that define the elements in relation to each other, but also their total effect as a design and technology solution in the applied setting. In a very real sense, technology is the product of the schema interacting to satisfy a need or an aspiration.

Conclusions: Basic Principles in Holistic Technology Education

Teachers who seek justification for deciding what may constitute the minimums of holistic solutions in design and technology may refer to the schema proposed here. A holistic understanding of technology develops through structured or enabling-learning experiences that make explicit, in detail, the interconnectedness of human, *tool,* and environmental factors, where these three factors mutually require and define each other and act as both resources and constraints in the applied setting. The schema gains strength through historical examination of the nature or phenomenon of technological activity where not only are all three factors defined by each other, but design and technology experiences, if taught holistically, as interconnected, are a *condition* to new knowledge creation. Technology education is not merely a *know-how*, but necessarily must be understood and presented in the curriculum to learners as a *know-why* subject. Only then may there be reasoned claims to technology being learned holistically. Peters provides a fitting end:

> We would not call a man who was merely well informed an educated man. He must also have some understanding of the reason why of things. The Spartans, for instance, were militarily and morally trained . . . But we would not say that they had received a military or moral education; for they had never been encouraged to probe into the principles underlying their code. (1971, p.8)

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School Graduation Project in Robot Design: A Case Study of Team Learning Experiences and Outcomes

Igor M. Verner and Eyal Hershko

Introduction

The field of technology education is undergoing intensive curricular revision to accommodate the contents and practices required by the new Standards for Technological Literacy (International Technology Education Association, 2000). The United States National Commission on the High School Senior Year released a report including recommendations for better preparation of secondary school graduates for tertiary education and professional careers (Panel Calls for preK-16 Education, 2001). One of the proposed changes was to introduce a senior project, which would provide a student with options of internship, research, and community service. Grubb, Davis, Lum, Plihal and Morgaine (1991) characterized the senior project as a model for integrating vocational and academic education. Accordingly, the project carried out would include hands-on experience in vocational workshops, research, problem solving, and presenting findings. Many American schools and school districts have developed and released guides to graduation projects on their websites (Goldsmith & Belasli, 2001). Similar programs are instituted in Great Britain and Israel. With this international effort to introduce projects into school curricula, there is a need to substantiate it by case studies of learning contents, processes, and assessment of specific projects as a source for case-based reasoning (Kolodner, 1993) and conceptualization of educational approaches.

Many educators believe that robotics is a suitable subject for project- based education in high schools (Beer, Chiel & Drushel, 1999; Wedeward & Bruder, in press). Learning through designing, building and operating robots can lead to the acquisition of knowledge and skills in high-tech electrical, mechanical, and computer engineering areas that are in high demand in industry. It can promote development of systems thinking, problem solving, self-study, and teamwork skills. Involvement of students in a robot contest can offer additional educational benefits including the following (Verner, Ahlgren & Mendelssohn, 2000):

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- The contest provides a focused, open-ended, interdisciplinary project that is a strong motivator of student creativity, self-directed learning, and research.
- Through cooperation and the development of professional relationships within and beyond the contest community, students develop and strengthen their teamwork and communication skills.
- Students become keen on designing robots and enjoy participating in the contest.

The above-mentioned potential advantages motivated the Israeli Ministry of Education to initiate a program of graduation projects in robotics and support participation of school teams in robotics contests. This paper presents a case study of learning and instruction in robot design projects performed in one Israeli high school (Mevohot E'ron High School), aiming to promote its further implementation and investigation of educational factors involved.

Graduation Project Framework

In Israel, the graduation project is an optional matriculation subject in the form of a self-directed assignment in science, technology, or humanities. Directions given by the Ministry of Education define its contents (a scientific subject studied through analysis, synthesis, and evaluation), emphases (self-directed learning, science research methods, critical and creative thinking), and features (relation to high school discipline, a topic of student interest, a project including creative design and theoretical study). Projects are carried out individually or in groups of up to three students. The students start by preparing a project proposal and submitting it for approval, and finish by issuing the project report for external assessment. The report should document project activities and results and specify individual contributions of each student. Project assessment consists of:

- Demonstration of theoretical approach and deep understanding of the subject - 60 pts.
- Reports on experiments, observations, and interviews conducted by the student; originality and creativity - 10 pts.
- Relevant description, standard grammar, and clear explanation - 10 pts.
- Correct use of quotations, bibliography, numbering, illustrations and graphs - 10 pts.
- Appearance: easy to read, aesthetic - 10 pts.

The graduation project in technology is directed at integrating practical designing and building a product with research in technology and application of scientific methods. Many graduation projects prepared in the last five years relate to designing, constructing, and operating robots and have been carried out in connection with the Machine Control discipline (Verner, Waks & Kolberg, 1997; Verner & Betzer, 2001).

A number of schools are implementing robotics projects inspired by the fire-fighting robot contest program (Ahlgren & Mendelssohn, 1998). Since the 1998-1999 school year, high school students in Israel have participated in the international Trinity College Fire-Fighting Home Robot Contests (TCFFHRC) in Hartford, CT, USA, and in the local robot contests organized by the Israeli Ministry of Education. The Israeli delegation at the TCFFHRC included 24 students and 5 robots from five schools in 1999, 73 students and 8 robots from seven schools in 2000, 81 students and 10 robots from seven schools in 2001, and 112 students and 17 robots from nine schools in 2002.

The objective of our study is to examine learning through designing robots in the framework of school graduation projects. This paper presents the results of a case study of the fire-fighting robot projects developed in one of the schools in 1999-2002 with stress on the following research questions:

1. Which subjects should teachers address as students design robotics systems, and how should they be integrated into the graduation projects?
2. What are the learning objectives and activities at different stages of robot design?
3. How should individual contributions and learning achievements in the team project be assessed?

These questions relate to the three principal aspects of the graduation project as an educational design experiment (Brown, 1992): content knowledge, learning process, and authentic assessment. Question 1 focuses the study on theoretical subjects and practical skills learned in the fire-fighting robot project, and instructional methods to introduce them to high school students. Question 2 concerns instructional objectives and learning activities throughout the project. Experience in project guidance shows that different stages of robot design are related to distinct learning activities. Therefore, the study should examine each of the design stages. Question 3 arises from the need to assess the learning achievements of each student participating in the team project. It directs the study toward finding assessment criteria authentic for the teacher and the student. Answering the above questions through a case study was important for success of the fire-fighting robot projects in the Mevohot E'ron High School.

Fire-Fighting Robot Assignment

The TCFFHRC attracts a wide range of designers, including faculty and engineers, graduate and undergraduate students, as well as high school and junior high school pupils. The participants compete in one of several divisions (experts, senior, high school, junior). The contest assignment (Ahlgren & Mendelssohn, 1998) is to develop a mobile robot that can navigate autonomously through a model house, find a lit candle placed at random in one of the rooms, and extinguish it. The maze includes four rooms and connecting hallways with black floors and white walls. White lines mark the rooms' thresholds. Each robot's score in the contest is the sum of the fastest two run times of the allowed three runs. These basic rules are extended by additional rules modified each year, which determine maze dimensions, robot characterisitics, and bonus and penalty factors, and which specify contest presentations and scoring. Detailed rules are released on the contest website:

http://www.trincoll.edu/events/robot/

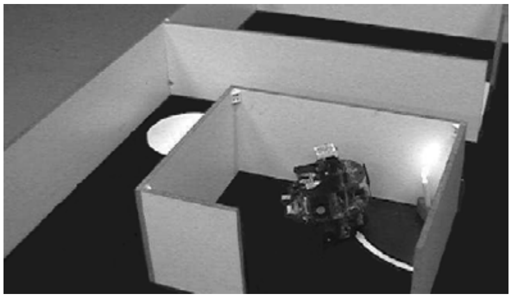
Fire-Fighting Project in Mevohot E'ron High School

A fire-fighting robot project at the Mevohot E'ron High School has been developed since 1998 by a technology teacher (Hershko) in connection with his graduate studies at the Technion. In 1999-2000, the Mevohot E'ron robot team consisted of 13 students, all males with diverse background levels in mathematics, physics, and technology. They were divided into five groups which dealt with structure, sensors, fire extinction, software, and management. The structure group designed and built the robot structure. The sensors group was responsible for the calibration of sensors and motors and the kinematics of straight and circular robot motion. The fire extinction group examined several possible solutions for extinguishing candles and chose a suitable propeller device, mounted it on the robot, and tested it. The software group dealt with maze navigation logic and programming robot movements. The management group coordinated the project schedule, logistics, reports, and presentations. The team participated in the TCFFHRC 2000 and shared places 12 to 16 (among 48).

As a result of careful evaluation of projects in the 1999-2000 school year, including the TCFFHRC 2000, several improvements were made in the 2000-2001curriculum. The team consisted of 8 students, 6 males and 2 females, with diverse background levels. It was divided into two groups of equivalent amount of project work and responsibilities: structure and fire extinction (S&FE), and sensors and software (S&S). The S&FE group examined a number of variants of robot structure and fire extinction means through physical and mathematical modeling and CAD. The S&S group dealt with robot kinematics, application of shaft encoders for position control, and algorithms and software for maze navigation. The team developed another fire-fighting robot, which took seventh place (among 36) in the 2001 Trinity contest. Figure 1A shows the robot after finding the lit candle in the maze and ready to complete the task by extinguishing the candle.

The 2001-2002 project involved 25 students, all males of different background level and ethnic origin, divided into three teams who worked on three new and different fire-fighting robots. The first team built a 20_20_30 cm^3 robot with a caterpillar drive system for the expert division contest. The second team developed a tricycle robot of the same size and the third team designed a tiny fire fighter, 10_10_15 cm^3 (see Figure 1B), both for the high school division. The teams designed robots following the general outline developed in the 2001 project.

All 46 members of the Mevohot E'ron fire-fighting robot teams in 1999-2002 were 12th grade students who voluntarily chose and successfully completed school graduation projects in robotics. They formed the research population of the case study conducted in connection with the projects.



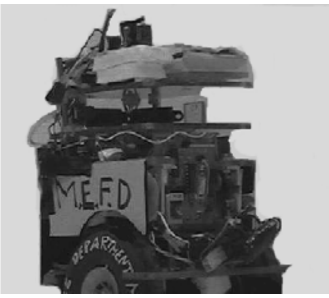


Figure 1. The 2001 robot in the maze (left) and the 2002 Tiny Fire Fighter (right).

Project Outline

The project was conducted through a sequence of regular work meetings of the subject groups and the whole team. The meetings were in two stages: preparation and project work. Preparation meetings were conducted by an instructor twice each week. In these meetings the instructor introduced the process of building a fire-fighting robot. At these meetings the students put into practice subjects studied theoretically in the technology course. They operated DC motors, made drawings using CAD tools, calibrated sensors. and analyzed data on EXCEL spreadsheets. From our experience, these activities helped the students realize the value of the project and acquire the confidence to face its challenge.

The project work meetings were managed by students themselves and were directed purposefully toward the project goal. At these meetings the students recognized the range of tasks included in the fire-fighting robot design process and performed them. The main tasks are presented in Table 1.

When performing the robot design tasks specified in Table 1, they were divided between the structure and software groups of the team as follows: the structure group was responsible for M1-M3, I1, and P2; the software group carried out S1-S3, and I2; the rest of the tasks C1-C4, I3, and P1 were performed through collaboration between the groups.

Parallel to performing the tasks specified in Table 1, the students prepared graduation project reports. The structure and software groups were divided into subgroups of one to three students. Each of the subgroups documented its collective and individual activities in a separate portfolio and, at the end of the project, summarized the results of its theoretical and practical learning in the project report.

The report presented a range of experiences including the teamwork overview, the group collaborative work and its results, and the personal contributions of the students. In the teamwork overview the students described

Table 1

Tasks and Products in the 2001 Project

Task	Products
Mechanical modeling of robot structure, drive mechanism, and extinguishing device	
M1. Design 2-3 possible solutions for robot structure and drive mechanism	CAD technical drawings, cardboard models and specifications
M2. Place sensors on each of possible robot structures	Sensor and extinguishing device; substitutes attached to the cardboard models
M3. Design a special extinguishing device for each of possible robot structure solutions	
Sensors and control	
C1. Develop a control method for robot motion along maze hallways with a given distance from its walls	A sensor configuration and control algorithms
C2. Develop a method for detecting the position and orientation of threshold white lines on the maze floor	
C3. Develop a method for detecting obstacles	
C4. Develop a method for detecting fire	
System software	
S1. Develop a navigation program for robot motion from each room to any other room in the maze	Interactive C modules tested on the standard mobile robot
S2. Develop a program for identifying each room of the maze	
S3. Develop a program for avoiding obstacles	
Robot implementation	
I1. Build the robot platform including motors, sensors. and the extinguishing device	A physical robot platform
I2. Adapt the system software modules to the project robot	The Interactive C modules tested on the project robot
I3. Integrate the algorithms of specific robot behaviors into an entire procedure for the contest assignment	Robot system software
Contest presentation	
P1. Provide robust performance of the contest assignment in diverse situations	A reliable robot system
P2. Fashion an aesthetic outward appearance of the robot	An aesthetically fashioned robot

the structure and functions of the robot system and the principles behind its development. In relation to group work, the students discussed in detail the problems, methods, experiments, and practical activities in the subjects in which they were involved. When telling about their personal contributions, the students specified their involvement in robot subsystems and types of activities at each of the robot design stages. They also provided overall reflections about the project.

Research Methods

The educational study approached the fire-fighting robot program of the Mevohot E'ron High School both from the action research aspect, i.e.. a "self-reflective enquiry in order to improve the productivity, rationality, and justice" of graduation projects in robotics, as well as from the theoretical underlying factors in order to understand the "educational practices and the situations in which the practices were carried out" (Kemmins, 1999). A faculty member (Verner) directed and shaped the study, and conducted the contest survey. A teacher (Hershko) guided the projects and conducted the study in his school. The field research data throughout the project were gathered from two main sources: the team portfolio and the teacher's logbook. The portfolio included a sequence of protocols of team meetings where specified tasks, experiences, solutions, and decisions were discussed. The teacher's logbook included results of quizzes, guidance notes, and observations of students' activities throughout the project. Graduation project reports provided the main source for summative assessment of learning achievements.

The study examined learning in the fire-fighting robot projects with focus on three aspects:

- Engineering knowledge and skills in designing robots and how they could be addressed in the high school graduation project.
- Learning by reflective practice directed at facing the challenges of the robot contest.
- Individual assessment of learning achievements in the team project.

Designing robots as engineering systems which combine mechanical, electrical, computer, and information technologies is studied in mechatronics (Wikander, Torngren, & Hanson, 2001). When examining the various aspects of the fire-fighting robot design we relied on mechatronics texts (Shetty & Kolk, 1997; Tomkinson & Horne, 1996), while a book (Jones, 1999) was a source of robotics experiments. Only subjects relevant to the project assignment, connected to the Machine Control curriculum (Verner & Betzer, 2001), and adapted to high school learners were selected. Designing robots was taught throughout the project: at the preparatory stage by traditional experiments and at the project work stage through performing creative tasks or “design challenges” (Sadler, Coyle & Schwartz, 2000).

In teaching principles of the design process and guiding the fire-fighting robot design project, we applied the methodology of “total design” proposed by Pugh (1991). The advantage of the Pugh model is that it fits the four principal features of the design process required by the International Technology Education Association (2000):

- Flexibility – a sequence of stages combined with cyclical processes.
- Balance – an integration of mechanical, electronic, computer, and control components.
- Function – a purposeful process culminating in manufacture and sell.
- Proportion – a systematic consideration of various factors.

The six stages of the engineering design process in the Pugh model are market, specification, concept design, detail design, manufacture, and sell. To adapt the model to an instructional design process, we renamed some of the stages and added specifications presented in the first column of Table 2.

Table 2
Stages and Contents of the Design Process

Learning objectives	Stages
Definition of needs and demands and formulating the project proposal	1. Project idea: Recognizing the need
Finding, examining and making decisions on how to implement the project through recognizing sub-problems and approaches	2. Specification: Concept layout, spatial allocation
Finding feasible solutions and their analysis through theoretical considerations and experiments. Formulating the best solution concept in terms of components and processes	3. Concept design: Subsystem design and analysis
Systematic consideration and implementation of the best solution through iterations of creation, integration. and functional testing of product sub-systems. Product testing in laboratory conditions	4. Detail design and creation: Component design and analysis, creation and testing prototypes
Testing the product in a real environment in diverse (including extreme) situations. Improving the product toward a more effective, reliable, and aesthetic performance	5. Operation and tuning: product exploitation and maintenance practice
Public presentation and demonstration of the product. Preparing a project report and external examination	6. Evaluation: Presentation of learning results, assessment

Learning activities in different robot projects, including fire-fighting robot projects, are intensively discussed in literature (Beer, Chiel & Drushel, 1999; Wedeward & Bruder, in press). In these studies the activities are considered in relation to the design process as a whole. Our study proposes and implements a different approach, namely, learning activities are specified with regard to the stages of the design process as shown in Table 2. This approach helps to plan and manage teamwork in the project.

Educational evaluation and assessment in this study is based on ethnographic observations of the teamwork, examination of learning achievements, and analysis of the TCFFHRC Survey (Verner, Ahlgren & Mendelssohn, 2000). Educational surveys were carried out at the 1999, 2000 and 2001 fire-fighting contests at Trinity. They assessed the learning outcomes of contest-oriented curricula and attitudes of the participants to the program. The contestants were asked to fill out survey forms. The survey sought the following information: progress in disciplines gained by working on the contest project, forms of participation in the robot contest program, personal contribution to robot subsystems, motivation for participation in the contest project, and contribution of the contest to attitudes toward robotics and engineering.

Answers given by the Mevohot E'ron team members to the survey questions reflected their personal involvement and views on the project. The teacher explained the questions to the students before they filled the forms and got oral explanations of their answers after the survey.

Findings of the Research in Class

The analysis of the teacher's logbook and students' portfolios focused on notes related to the different stages of the design process (see Table 2). At the first stage of shaping the project idea, the central didactic objective was motivation, i.e., to provide the students with the incentive to meet the challenge of the project and put in the effort to bring it to completion. This was a time-consuming process. It included such important features as watching and discussing a video of the prior robot contest, meeting with members of the previous year's team, and, of course, the personal enthusiasm and charisma of the teacher. Our study suggests that incentive was achieved, as indicated by the following student behavior:

Contributing time to self-directed extracurricular teamwork

From the first work meeting, all of the students stayed extra hours and held additional meetings in the laboratory beyond the time formally assigned for project guidance.

Curiosity and motivation in inquiring about project-related subjects

During the project, the students managed informal consultations with their teachers of physics (in optics), biology (sensing biological systems), and chemistry (on chemical means of fire-fighting). They conducted extensive Web searches (robot navigation algorithms, sensors, drive mechanisms) and read recommended textbooks (design theory, mobile robots, and analog electronics).

Concentrating on solving project-related problems

> From the responses of teachers and parents cited in the logbook, the students were deeply involved in the robotics problems and continually discussed them during the project. Of their own initiative the students developed and implemented in the project such robot design ideas as an artistic outward appearance, disposition of sensors, and an optimized kinematic scheme.

Taking a personal initiative in project promotion

> At the beginning of the project the team was advised to divide the assignment between two crews (structure and software). Later on, they divided the crews into sub-crews in order to examine alternative approaches to problems. Being involved in the organizational and economic aspects of the project and recognizing the need of funding the project, the students themselves approached potential sponsors (companies and a municipality).

Feelings of empathy toward the robot

> The students gave the robot a name (Aurora) and gender (female), as reflected by its outward appearance. The minutes indicated that the students considered the robot as a co-partner. For example, one of the students wrote: "Today the robot did not like me."

Our study indicates high motivation and involvement of the students in the fire-fighting robot project. All 46 students who selected the project successfully completed it and prepared graduation reports. However, we should mention that the project attracted mainly male students. Only two of the participants were females (4.3 %).

In the second stage of the design process (specification), the didactic focus was on the development of technological systems thinking skills, as defined by the International Technology Education Association (2000, 32-43). We found that learning achievements depend on the selected model of the design process. In 2000, the stages in the design process were performed as separate step-by-step tasks, concentrating on activities in mechanics and control. In 2001, we turned to a multifaceted iterative design approach (Pugh, 1991). This change provided students with involvement in a wider range of aspects of the fire-fighting robot design.

At the concept design stage, the emphasis was on students' understanding and shaping of possible solutions and on collaborative decision-making of an optimal solution for each design problem. This was achieved through gathering technical data and making real-world experiments. Unlike professional designers, the students needed to build physical prototypes in order to focus their thoughts when examining solutions. The students mentioned that through building the prototypes they discovered new problems, of which they had been unaware at the previous design stage.

Detail Design and Creation (DDC) was the stage at which the students implemented the optimal solutions found in the earlier stages of design. This was performed through the coordinated work of the software and structure crews. The structure crew was concerned with building the robot. The students planned the robot assembling process, ordered relevant standard parts, and manufactured special parts for the project by carving, milling, drilling, and soldering. The software crew received the physical robot from the structure crew and wrote a computer program adapted to it. The central didactic issues at the DDC stage were 1) involving the students in a variety of activities, 2) promoting their technological creativity, and 3) planning collaborative work.

At the operational and tuning stage, when the robot was already built and its functions had been programmed, the team performed systematic tests to integrate the functions and execute the contest assignment in various real conditions. While in many other graduation projects the students are not required to test and improve their products systematically, in the fire-fighting robot project the incentive to achieve a complete product and succeed in the contest motivated the students to maximum effort at this stage. Intensive practice in testing and improving the robot led to the development of "the abilities to use and maintain technological products and systems," which are required from school graduates by the Standards (International Technology Education Association, 2000). A negative finding detected by the study was that the teams did not assign sufficient time for this stage of the project and, as a result, were overworked before the contest.

Contest Survey

Here we used the data from the contest survey for a summative evaluation and assessment of the project with focus on two survey questions. One of these questions asked each team member to estimate his or her progress resulting from participation in the project in the following 17 subjects: electronics, computer communication, microprocessors, assembly language, high-level language, motors and gears, mechanical design, robot kinematics, sensors and measurement, data analysis, physical field concepts, mathematical modeling, control systems, CAD tools, systems design, robot programming, and teamwork.

For each field the students evaluated their progress in theoretical and practical knowledge. In addition, the teacher estimated the progress of every student in the above fields. Teacher’s estimates based on quizzes and logbook records took into account that the subjects were studied during the course at different levels of detail. Students’ evaluations and teacher’s estimates were compared.

The answers revealed that each of the students had made progress in the absolute majority of subjects in both theoretical and practical domains. The teacher reported a lack of students’ progress in some subjects only in 14.3% of cases and the students themselves in 9.3% of cases.

Substantial progress was mainly achieved in programming, robot kinematics, sensors, data analysis, control, and teamwork. Especially high progress was reported in programming, robot kinematics, sensors, data analysis, control, and teamwork, i.e., in the subjects that were central to the project activities. Thus, the teacher’s grades and students’ self-assessment rates both claimed that the course achieved its goal of imparting interdisciplinary knowledge in both theoretical and practical domains. A similar effect of integrated learning through designing, building, and operating robots was achieved and analyzed in our former study (Verner, Waks & Kolberg, 1997).

A high level of agreement was found between the students' self-evaluation and the teacher's assessment. In 50.9% of the cases, results of the two assessments were absolutely identical. In 32.1% of the cases the students' self-evaluation ratings were lower than the teacher's. A possible reason for this underestimation is the students' self-criticism and inexperience in assessment. In 17.0% of the cases, ratings of students were higher (overestimation). The overestimations related mainly to subjects that were new for the students and were studied at the basic level. The comparison also showed that the students evaluated their progress at different levels of objectivity.

In the second survey question, the team members were asked to describe their own practical activities with main robot components, namely, drive mechanism, mechanical structure, micro-controller, control circuits, sensor system, steering planning, system software, and the extinguishing device. For each component, they were asked to specify their involvement in various types of activities: Designing, Constructing, Testing, Implementing, and Installing. Students' responses (N=8) are presented in Table 3. Each of the rows informs about the involvement of a student in the robot development, while "+" denotes a specific activity with a robot component.

It is interesting to see clusters denoted by dashed rectangles in the table. They clearly indicate the two subgroups with different activities in the project: students 1-3 and students 4-7. This reflects the fact that teamwork in the project was managed in two subgroups, namely the structure and software groups, which divided functions and responsibilities.

Students 1-3 composed the structure subgroup. Four clusters present their exclusive contribution. The first cluster relates to the drive mechanism and robot structure, and shows involvement of each student in all five types of activities. As indicated by the second cluster, the structure subgroup dealt with the robot micro-controller, while the activities were only installing and testing. The third cluster is attributed to the steering planning subsystem, and the fourth one to the extinguishing device. Students 4-7 composed the software group. The only exclusive cluster for this subgroup is the system software, but its contribution to the robot is not less than that of the structure group. The "sensors" cluster indicates the common contribution of the two subgroups through involvement in all types of activities. The contribution of student 8 was in all of the subsystems. This student was the team leader.

Our study also detected the same effect of cluster-shaped division of project work for the three teams that developed fire-fighting robots in 2001-2002. Social interaction between students will be dealt with in another article.

Table 3
Students' Involvement in the Robot Development

	Drive					Structure					Controller					Circuits				
	Student	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing
1	+		+	+	+		+	+	+	+			+		+					
2	+		+	+	+		+	+	+	+			+		+					
3	+		+	+	+		+	+	+	+			+		+					
4																				
5																				
6															+					
7																				
8			+					+	+	+			+		+					

	Sensors					Steering					Software					Extinguisher					
	Installing	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing	Installing	Designing	Constructing	Testing	Implementing	Installing
1	+		+	+		+	+	+	+	+			+			+	+	+	+	+	
2	+		+	+	+	+			+	+		+	+			+			+	+	
3	+		+	+	+	+	+	+	+	+			+			+	+	+	+	+	
4			+		+						+		+	+							
5			+								+			+				+			
6			+								+			+				+			
7	+		+	+	+						+	+	+	+	+			+			
8	+		+	+	+						+	+	+	+	+			+	+	+	

Conclusions

The importance of the school graduation project as an integrator of vocational and academic education should be recognized. Our case study shows its possible curricular standing as an optional matriculation subject that involves the student in a purposeful intensive learning of design and technology. We believe that the option to work on a project should be available to any interested senior high school student.

Robotics is one possible subject for graduation projects. Since the 1998-1999 school year, a number of schools in Israel have developed projects inspired by the challenge of fire-fighting robot design. They participated successfully in local contests organized by the Ministry of Education and in the international Trinity College Fire-Fighting Robot Contests. Our case study examined the fire-fighting robot projects developed in one of the schools during 1999-2002 and focused on the assessment of learning while working in the robot design teams. Results of the case study provide support to the following answers to the three research questions posed in the introduction.

1. Among the major topics stated in the Standards for Technological Literacy (International Technology Education Association, 2000, 211-214), the robotics projects centered on those related to the sections on “Design” and “Abilities for a Technological World.” When developing fire-fighting robots to fit contest requirements, the students went through all stages of the interdisciplinary design, as defined by Pugh, and built working prototypes of mechatronic systems (robots). They made significant progress in various engineering subjects and acquired technological and teamwork skills.
2. While carrying out the project, the students went through the preparation and six design stages: project idea, specification, concept design, detail design and creation, operation and tuning, and evaluation. These stages are essentially different in relation to their subject matter and learning contents. Therefore, our case study included a detailed analysis of tasks, learning objectives, and typical student behavior at all stages of the fire-fighting robot design. We believe that this analysis was crucial for effective guidance and authentic assessment of the project.
3. Individual assessment of contribution and learning achievements in the team project requires triangulation of ethnographic observations of the teamwork, examination of learning achievements, and an analysis of the students’ reports. The assessment and self-assessment data in our case study were gathered from three main sources: a team portfolio, a teacher’s logbook, and a contest survey. These gave a detailed picture of each student’s involvement in the robot design, learning achievements, motivation and attitude toward technology.

The main conclusions of the article are valid only to the specific conditions of this case study. Further research of robot design projects in other schools has to be carried out before general conclusions can be reached.

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Partnership-Centered Learning: The Case For Pedagogic Balance In Technology Education.

Brad Walmsley

Introduction

In many parts of the world, technology education is a subject area in transition (Eggleston, 1992; Fritz, 1996; Lauda, 1988; Wicklein, 1993). This has, and continues to be the case in countries such as America (Newberry, 2001; Sanders, 2001), the United Kingdom (McCormick, 1997) and Australia (Fritz, 1996). In each of these aforementioned countries, various modifications to standards statements (ITEA 2000), curriculum documents (QCA, 1999), and technology syllabi (QSA, 2002a; QSCC, 2000) are currently being drafted and redrafted. Curriculum reform in technology education seeks to modify the workshop-based industrial arts tendency to focus on industrial hand and machine skills (Young-Hawkins & Mouzes, 1991) to a focus more concerned with critical and creative higher-order thinking skills (Lee, 1996). These types of technology subjects are designed to respond to societal changes, such as those evident in many of the world's current post-industrial technological societies (Lauda, 1988).

The traditional pedagogy of workshop-type industrial arts subjects was, and in many cases still is, "show and follow" (Fritz, 1996, p.212), and it has been used to good effect in the building of student competencies, particularly industrial skills. However, technology education's evolution is transforming the subject from one that requires students to imitate teacher-prescribed industrial hand and machine skills to one that is argued to be unique in the school curriculum (Williams, 2000). Technology education is evolving to become a subject that is concerned with an individual student's ability to solve real world problems by integrating specifically relevant knowledge of materials, technological processes, and systems (Eggleston, 1992; QCA, 1999; QSA, 2002b). Technology education students are encouraged to reflect on and modify their thinking through their involvement with some form of technological design-type process. For example, the National Curriculum for Design and Technology in the United Kingdom (QCA, 1999) places importance on each student's ability to combine both the practical (hand skills) and theoretical

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(thinking skills) during their individual and group technological problem-solving activities by stating that students are expected to:

> … learn to think and intervene creatively to improve quality of life. The subject calls for pupils to become autonomous and creative problem solvers, as individuals and members of a team. They must look for needs, wants and opportunities and respond to them by developing a range of ideas and making products and systems. They combine practical skills with an understanding of aesthetics, social and environmental issues, function and industrial practices. As they do so, they reflect on and evaluate present and past design and technology, its uses and effects. Through design and technology, all pupils can become discriminating and informed users of products, and become innovators. (p.15)

By endorsing documents such as the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), the International Technology Education Association (ITEA) emphasizes the requirement for students to become technologically literate. The focus through this and other documents is to define a set of curricula standards for use in all American states that promotes the development of technological literacy in students. One of the principles that guided the formation of these standards is the requirement for students to participate in “active and experiential learning” (ITEA, 2000, p.3). The document, *Technology for all Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996) provides further support for recognition of the importance of combining both thinking and practical activities during a technological design process. This approach to curriculum formulation is argued to be significant in terms of developing the technological literacy of students (ITEA, 1996; Lewis & Gagel, 1992). The Technology for all Americans document states that:

> The technological design process involves the application of knowledge to new situations or goals, resulting in the development of new knowledge. Technological design requires an understanding of the use of resources and engages a variety of mental strategies, such as problem solving, visual imagery, and reasoning. Developing these mental abilities and strategies so that they can be applied to problems is a significant aspect of technological literacy. These abilities can be developed in students through experiences in designing, modeling, testing, troubleshooting, observing, analyzing, and investigating.” (p.18)

The recent changes in technology syllabi (Australia), curriculum documents (United Kingdom), and standards statements (America) are requiring that teachers and students acknowledge and embrace a restructuring of the balance of instructional power. The technology learning environment is currently undergoing a transformation from one that incorporates predominately teacher-centered teaching and learning strategies to one more oriented to student-centered learning. For example, the current *Industrial Technology and Design Subject Area Syllabus* (IT&D) in Queensland, Australia (QSA, 2002b) has been formulated in response to the *Technology Key Learning Area Syllabus* (QSCC, 2000) and emphasizes the requirement for teaching strategies that facilitate particular types of student- (learner) centered learning activities. The IT&D syllabus document states that:

> A learner centred approach provides opportunities for students to practise critical and creative thinking, problem solving and decision making. These involve the use of knowledge, practices and dispositions such as recall, application, analysis, synthesis, prediction and evaluation, all of which contribute to the development and enhancement of conceptual understandings. A learner-centred approach also encourages students to reflect on and monitor their thinking as they make decisions and take action. (p.13)

For both teachers and students in technology education, the traditional norms or expectations (Talbert & McLaughlin, 1993) associated with teaching and learning are now changing. Students are expected to become more autonomous toward their learning, and teachers are expected to facilitate this type of student learning activity. However, an apparent paradox exists within the subject's transition, and this may serve to hinder the change of focus from teacher- to student-centered learning. The paradox for both teachers and students is the necessity for teachers to demonstrate for students the safe and proper use of a range of hand, machine, and computer skills, as well as model for students a range of technological problem-solving skills. These types of skills provide students with the opportunity and facility to fulfill the various requirements of the technological design process, regardless of learning environment type. For example, students participating in CAD lessons initially require some form of teacher exposition of the necessary skills to facilitate their competent use of the CAD program. Once known and understood, this knowledge serves to support student-initiated design and problem-solving activities within the same CAD learning environment. Similarly, more traditional workshop environments support students' procedural abilities, in terms of hand and machine skills, until students are adept at applying these previously acquired skills during their technological design activities.

Therefore, technology education as a subject area has not necessarily devalued the traditional hand and machine skills of workshop industrial arts-type subjects, but rather it has revalued these skills in conjunction with cognitive problem-solving skills to have particular significance within the technological design process. For both teachers and students of technology education, the prescribed need to continue with teaching strategies that are associated with the norms of industrial arts-type subjects, creates tensions (Engestrom, 1993, 1999). These tensions occur as a result of changes in technology syllabus focus (i.e., from industrial skills to thinking skills) and the subsequent pressures these changes impose upon teachers and students with regard to the redistribution of learner and teacher pedagogic control. It is not suggested that the skills-based curriculum constructed from the industrial arts syllabi of the recent past totally disassociated students from using thinking skills. However, it is argued that traditional industrial arts programs focused more on skills-based instruction, and that the current expectation is for technology education to focus instead on a student's technological problem-solving abilities using cognitive, hand, machine, and other skills provided by teachers or acquired by students directly for this purpose.

The need to develop both hand skills and problem-solving abilities requires technology teachers to walk a pedagogic tightrope. On the one hand, teachers need to develop in students a degree of manual dexterity in the use of materials and processes, using both hand and machine tools. These skills have been traditionally taught by a teacher-centered "show and follow" strategy, the most familiar and comfortable strategy for industrial arts teachers (Fritz, 1996). On the other hand, technology teachers need to facilitate with students the autonomous development of their own cognitive and metacognitive strategies when solving technological problems. These are created through their involvement with the technological design process (Deluca, 1992). It is argued that these types of learning environments require a teacher-facilitated student-centered pedagogy (Deluca, 1992; Johnson, 1996).

It is the balance teachers create between teacher-centered and student-centered pedagogies within their technology classrooms that influences how students perceive the learning situation, and ultimately how and what they learn in technology education (Deluca, 1992; McCormick, Murphy & Hennessy, 1994). Bell (2000) addresses the issue of balance between student-managed (centered) learning activities and teacher-directed (centered) learning activities by stating that:

> Learning is a dynamic process, and the location of the balance between teacher-directed and student-managed activities can likewise be expected to be always dynamic. The emergence of personal ownership of learning is the hallmark of a true student, and shifting the balance to foster the growth of such independence is perhaps the key challenge within teaching at this level. It is a challenge which must be approached sensitively as teachers recognise and respond to the needs of the individual. While the balance between teacher-directed and student-managed learning may not be critical, the direction in which it is moving for each individual certainly is. Learning partnerships develop as the strategies intermingle and the distinction between formal roles becomes blurred. In such partnership-centred learning the balance is found (p.149).

This paper argues that the concept of partnership-centered learning (Bell, 2000) provides a more optimal teaching and learning strategy for providing the required dynamic balance between teacher exposition and student autonomy in technology classrooms. That is, as the technology learning situation dictates, teachers must adjust their teaching strategies from learner- to teacher-centered (e.g., from student autonomy to teacher exposition). It is the continually adjusting learning partnership created between teachers and students that helps to facilitate the desired higher-order thinking outcomes of students (e.g., critical and creative thinking, problem solving, and decision making), which are said to be encouraged by the technological design process (Williams, 2000). To support this argument, this paper presents the results of a study conducted by this author as an honors thesis requirement. It examined the cognitive activities of year nine and ten technology students from ages13 to 15 years in technology education classrooms, and further details can be found by using the reference to Walmsley (2001) in this paper.

Technology Education and Higher-Order Thinking

In acknowledgement of the lack of empirical research into the cognitive activities of technology students (Johnson, 1997) and in "particular of what teachers and students actually do in classrooms" (McCormick, 1996, p.72), a study of 480 year nine and ten students in Queensland state and independent high schools was initiated to examine technology education classrooms. This study focused on student perceptions of their own learning activities. Aspects of cognitive theory in the form of Cognitive Holding Power (Stevenson, 1998; Stevenson & Evans, 1994) were used to examine the relationship between students' use of procedural knowledge and the task environment in various technology classrooms. The Cognitive Holding Power (CHP) concept is defined as the press exerted by an educational learning environment, which causes students to utilize certain levels of procedural knowledge (see Stevenson & Evans for details). The press refers to the learning environments' influence on positive or negative goal attainment and is activated by the types of tasks with which students engage during their learning activities (Stevenson & Evans). Two factors that are interpreted as being most influential in terms of CHP are the teacher and the subject matter (Stevenson).

The CHP concept is significant because it interprets a learning environment's influence on students' use of different levels of procedural knowledge. Stevenson and McKavanagh (1992) interpret procedural knowledge in terms of hierarchies or orders. First order procedural knowledge is defined as knowledge of how to perform specific skills, much the same as the industrial skills that students in traditional industrial arts-type technology learning environments would be expected to perform. Second order procedural knowledge is defined as knowledge of how to apply problem-solving skills that assist with the application of previously acquired first order skills and conceptual knowledge to new and unusual situations. Second order procedural knowledge would be expected to be evident during students' technological problem-solving activities (higher-order thinking) in design process-based technology education classrooms (Garcia, 1994). Third order procedural knowledge is defined as knowledge whereby judgments can be made as to the appropriateness of all other levels of knowledge in specific circumstances. Of particular significance for technology education is the ability of the CHP construct to differentiate between learning environments that press for either first order procedural knowledge, learning environments that have first order cognitive holding power (FOCHP); or learning environments that press for second order procedural knowledge, learning environments that have second order cognitive holding power (SOCHP) (Stevenson, 1998).

An instrument has been developed, validated, and found reliable (Stevenson, 1998; Stevenson & Evans, 1994) in assessing learning environments relative to students' perceptions of the press for different levels of procedural knowledge. The Cognitive Holding Power Questionnaire (CHPQ) requires students to respond to 30 questions that relate to the amount of control students perceive they or their teachers have over their learning activities. Each question in the CHPQ requires students to respond to a five-tiered Likert scale, ranging from *almost never* to *very often*. Questions such as, "I ask questions to check my results" and "I try out new ideas" require responses that indicate the students' perception of a learning environment that presses for student control (SOCHP). Questions such as, "I copy what the teacher does" and "I feel I have to work exactly as I am shown" require responses that indicate the students' perception of a learning environment that presses for teacher control (FOCHP).

The study examined independent and public high schools in the southeast corner of Queensland, Australia. The 480 students in the nine high schools studied provided a statistically significant number of responses to the CHP questionnaire. These schools were selected because they each had previously implemented the developing years 1 to 10 technology syllabus (QSCC, 2000) on a trial basis during the 2000 school year. This provided each school with prior knowledge of the changing focus of the technology curriculum. On the basis of this prior knowledge, each school's Head of Technology Education Department (HOD) rated his own department's teaching orientation as being either design-based, manual arts-based, or a combination of the two. In many Queensland high schools, the subject title "manual arts education" is used to define an industry-related subject area that in other parts of the world would be best recognized and defined as "industrial arts education." The rating process was conducted in consultation with the researcher and therefore enabled good consistency of description among schools as to the characteristics that constituted a design, industrial arts, or a combined technology learning environment. Fundamental to how HODs described their school's approach, was the extent to which students contributed to their own learning within a design process curriculum. These teachers (HODs), by their own volition, saw the difference between industrial arts and technology education as being one of student-centered learning (design/tech ed.) versus teacher-centered learning (industrial arts).

The study required each year 9 and 10 student to respond to a modified version of the Cognitive Holding Power Questionnaire (CHPQ) (Stevenson, 1998) after first providing parental or guardian consent. The modification of the CHPQ was restricted to the changing of the questionnaire's title to the Technology Environment Response Form (TERF).

Table 1
Distribution of Students Among Teaching Orientations by Grade Level and Gender

Teaching Orientation	Male Yr. 9	Male Yr. 10	Male Total	Female Yr. 9	Female Yr. 10	Female Total	Grand Total
Design Based	33	51	84	54	23	77	161
Industrial Arts Based	48	97	145	15	11	26	171
Combination Ind. Arts & Design	77	49	126	14	8	22	148
Total	158	197	355	83	42	125	480

The student responses to the modified version of the CHPQ were tabulated and recorded using the Statistical Package for the Social Sciences. Means and standard deviations of student responses regarding FOCHP and SOCHP were analyzed with reference to school teaching orientation, year level, and gender. Analysis of variance *F*- test (ANOVA), Univariate analysis of variance using Type III sum of squares, and Scheffe *post hoc* comparisons were conducted to determine the significance of between and within category responses (Bryman & Cramer, 1997; Field, 2000). In addition, a principal component analysis with Varimax rotation, and Cronbach's α reliability scores (Bryman & Cramer; Field) for the tested variables was used to interpret the reliability of the scales FOCHP and SOCHP, and the validity of the CHPQ construct. The results of this later analysis upheld the construct validity of the CHPQ and the reliability of the scales FOCHP and SOCHP. Table 1 displays the response numbers of students per variable.

Table 2
Mean Results for Cognitive Holding Power by Teaching Orientation

Teaching Orientation	FOCHP *M*	FOCHP *SD*	SOCHP *M*	SOCHP *SD*	*N*
Design Based	3.08	0.56	3.12	0.52	161
Combination Design/ Industrial Arts Based	3.09	0.54	2.96	0.52	148
Industrial Arts Based	3.07	0.68	2.92	0.58	171
Total	3.08	0.60	3.00	0.55	480

The study found that students interpreted an increased press for SOCHP relative to the extent of design-based teaching orientation in their technology learning environment. That is, technology subjects with a design-oriented teaching strategy exhibited a superior mean result for SOCHP to that of both industrial arts and the combined categories. However, the mean results for FOCHP were consistent across all three teaching orientations. Table 2 displays the mean results and standard deviations for FOCHP and SOCHP across teaching orientations.

Further investigations of these data using a one-way analysis of variance (ANOVA) (Field, 2000) for the effect of technology subject teaching orientation on CHP, found the relationship with SOCHP to be significant ($F = 6.322$; $p = 0.002$) but unsubstantial (adjusted R squared = 0.022). Further analysis (ANOVA) of the SOCHP means between the design-based and industrial arts-based learning environments only, indicates that the variation is more significant ($F = 11.093$; $p = 0.001$). However, the effect of teaching orientation on SOCHP between design- and industrial arts-based learning environments only, accounts for just 3% of the variance (adjusted R-squared = 0.03). The relationship between FOCHP and technology subject teaching orientation was found not to be significant ($F = 0.025$; $p = 0.98$). A Scheffe *post hoc* test of comparison between teaching orientations and SOCHP revealed that design-based learning environments were significantly superior to both industrial arts-based and combined design- and industrial arts-based environments ($p = 0.003$ and $p = 0.035$ respectively). However, no significant difference was discovered between industrial arts and the combined categories ($p = 0.79$).

Table 3
CHP by Gender, Level, and Teaching Orientation

Teaching Orientation	**Gender**	**Year Level**	**FOCHP** ***M (SD)***	**SOCHP** ***M (SD)***
Design Based	Male	9	3.05 (.49)	3.11 (.58)
		10	3.08 (.58)	3.04 (.55)
	Female	9	3.11 (.62)	3.22 (.48)
		10	3.04 (.51)	3.11 (.46)
Combined Design & Industrial Arts Based	Male	9	3.10 (.57)	2.95 (.53)
		10	3.04 (.55)	2.95 (.50)
	Female	9	3.26 (.40)	3.11 (.56)
		10	2.88 (.32)	2.88 (.51)
Industrial Arts Based	Male	9	3.30 (.47)	2.89 (.69)
		10	2.95 (.64)	2.94 (.63)
	Female	9	3.20 (.68)	2.93 (.67)
		10	2.94 (.58)	2.92 (.51)
Total Results	Male	9	3.15 (.60)	2.97 (.52)
		10	3.01 (.61)	2.97 (.58)
	Female	9	3.15 (.61)	3.15 (.54)
		10	2.98 (.50)	3.02 (.48)

Table 3 displays the mean results and standard deviations for gender across year levels and technology subject teaching orientation. Results for SOCHP and gender and year level in design-based learning environments reinforce the previous mean results found for SOCHP and design-based teaching orientation. That is, students in design-based technology learning environments relative to age and gender perceive a higher press for SOCHP than do other forms of teaching orientation. An analysis of variance for SOCHP between genders found a significant ($F = 5.80$; $p = 0.016$), but unsubstantial relationship (Adjusted R-squared = 0.010). The study provided no support for either gender or year level, e.g., classroom observations of teacher and student interactions, and as a result. no further data analysis was conducted of the significance of the mean results for gender and year level. However, the mean results for both gender and year level further support the overall significance of the results for subject teaching orientation, the construct validity of the CHPQ, and the reliability of the two scales of FOCHP and SOCHP.

Discussion

The results of this study of the cognitive activities of technology students in different types of technology learning environments indicate that students do experience an increased and significant, yet unsubstantial, press for second-order procedures (higher-order thinking, e.g., technological problem-solving) in design-based technology classrooms. Results also indicate that students are equally pressed for first-order procedures (skill development) throughout all forms of the technology learning environment, regardless of that environment’s design component. This empirical research evidence regarding students’ perceptions of their own learning activities provides support for the argument that design-based technology teachers are currently grappling with the need for some form of balance between teacher support (FOCHP) and student autonomy (SOCHP). It appears that students do perceive significant control over their learning in design-based classrooms. However, the study found that the extent of this student control was not substantial. The norms of current technology curriculum practice, which are rooted in teacher demonstration and exposition, continue to exist as a possible result of technology education’s craft traditions (McCormick & Davidson, 1996). These norms may be causing design-based teachers to balance their instruction in the direction of teacher control (Wiske, 1994).

These research results suggest that teachers do recognize the need to mix pedagogies (design: SOCHP and industrial arts: FOCHP) in order to balance their curriculum. However, the changing emphasis within all forms of technology curriculum documentation from industrial skill development to cognitive skill development, dictates that the balance between teacher-centered and student-centered learning should now favor the direction of the latter. It appears that design-based technology education teachers are currently adopting a more learner-centered approach to curriculum delivery, but are doing so while still maintaining a certain level of student perceivable control over what, how, and when students learn. These technology teachers may be placing more importance on the making (doing) phase of the design process in preference to (but not excluding) the thinking and planning stages (McCormick & Davidson, 1996). Now in the subject's evolving history, it appears that students perceive the balance between teaching strategies as being only marginally weighted toward the more student-centered strategies of the design process. The lecture and demonstration strategies of industrial arts education still appear to have considerable influence concerning how students perceive control over their learning. Hennessy, McCormick and Murphy (1993) consider that students superficially and mechanically follow a prescribed and sequential series of analyzing and monitoring tasks as a result of not only "lack of competence, but from the ways in which we [they] believe activity is structured in schools" (p. 83).

The tendency of technology students to follow, as argued by Hennessy, McCormick, and Murphy, is perhaps unknowingly perpetuated by the students themselves. For example, Grossman and Stodolsky (1994) argue that students unwittingly pressure teachers into the use of teaching strategies that match their preferred method of learning and that, "…students exert pressure on teachers to teach in certain ways; their perceptions of the subject may contribute to these expectations" (p.207). The historical roots of technology education in industrial arts education may be one factor that skews students' expectations toward learning in design-based technology classrooms in the direction of the traditional lecture and demonstration, teacher-centered approach. The possible consequence of students' expecting to learn in design-based classrooms through more traditional teacher-centered methods might be that teachers choose to teach to student expectations. Teachers may feel that they are violating the currently accepted norms (lecture and demonstration) of learning and teaching in technology education by adopting more student-centered, problem-solving type pedagogies.

In a study of creativity development and the design approach to learning in technology education, Davies (2000) found that the perceptions teachers and students hold of each other have an effect on creative endeavors and thus on student higher-order thinking. It is argued that students do not feel that teachers model the processes involved in creative activity and are therefore not considered competent in this area. Davies also argued that teachers underestimate student abilities and do not generally encourage students to take risks, which ultimately reduces the potential learning experiences of students.

Deluca (1992) studied the various teaching strategies used by exemplary technology teachers to encourage students during their technological problem-solving activities. Deluca found that strategies argued to be associated with higher-order thinking (SOCHP), such as panel discussion, role play, case study, seminar, and contract were used less often than strategies associated with lower-order thinking (FOCHP), such as teacher lecture and demonstration. Deluca therefore argued that teachers see the need to provide students with the basic conceptual and procedural information before allowing students the freedom to move on to more autonomous forms of learning. In other words, instructional methods change from teacher-centered to student-centered learning, as the teacher deems appropriate. However, one may argue that technology teachers who adopt this type of instructional tactic are predisposing students to the safety inherent in the instructional norms of industrial arts, rather than to the potential risks (by teachers and students) associated with the more independent types of student learning activity found potentially within the technological design process (Davies, 1999). Davies advocates a learning partnership between teacher and student by stating that:

> If the teacher chooses to make decisions on behalf of the student, they might not necessarily be acting in the best interests of the student overall. If teachers and learners share the risks associated with the learning process, better quality learning is likely to be achieved. (p. 107)

Conclusion

Curriculum reform for technology education teachers requires that they create with students a learning partnership, and that this partnership should promote learner autonomy. If students are to perceive a substantial level of control over their own learning (as required by technology curriculum documents), this partnership must favor student-initiated learning activity. The inherent value of the concept of partnership-centered learning (Bell, 2000) for technology education lies not so much in its yearning for pedagogic balance, but in the idea that traditional teaching and learning roles become blurred and that in the process, the direction of change (i.e., from teacher-centered to student-centered) becomes of more importance for the individual student than the overall extent of any change.

The Cognitive Holding Power Questionnaire (Stevenson, 1998) enables both teachers and researchers to measure how students perceive their technology classrooms in terms of either teacher- or student-controlled learning activities. Therefore, by measuring students' perceptions incrementally over set periods, an indication may be gained as to how students perceive the trend of pedagogic change in technology education rather than focusing only on the extent of that change. Lewis (1999) agreed with the need for classroom research that examines the relationship between learning outcomes and instructional reform in technology education. He stated that:

> …perhaps another way to approach this question [pedagogic change] is incrementally; that is, the researcher works *forward* from practice towards the ideal. Every increment of change along the way counts. Thus, there is need for subtle methods to measure change. Small changes might be more typical in practice, and it would be a mistake for the field to overlook them. (p.48)

This author's study of the cognitive comparison of learning in various forms of technology classrooms along the pedagogic continuum (i.e., from teacher-centered to student-centered learning) provides a starting point for measuring the cognitive effects of instructional reform in technology education. The accumulation of knowledge from empirical research conducted on actual technology classroom learning activities and student perceptions of pedagogic control may influence technology teachers to seek ways of supporting students' increased use of higher-order thinking processes. Technology teachers may achieve an increase in students' use of higher-order thinking by subtly redefining the optimal balance between teacher and student-centered learning in their own technology classrooms. Perhaps the optimal pedagogic balance in technology education is achievable using teaching strategies that blur traditional teaching and learning roles. Teaching strategies of this type may ultimately facilitate the formation of teacher and student learning partnerships in technology education.

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Book Review

Human Rights and Politically Incorrect Thinking versus *Technically Speaking*

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Pearson, G. and Young, T. (Eds.). (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC. National Academy Press. $19.95 (paperback), 156 pp. (ISBN 0-309-08262-5).

Published in 1963, *Technically Speaking* is a portrayal of technological literacy as engineers and technologists are wont to provide. Whoops! Wrong book, but the same can be said about the new *Technically Speaking*. There was a problem with the type of literacy that engineers and technologists were prone to advocate for themselves and others in 1963 and there is a problem now. Inherently conservative, both books exhibit the fence-sitting literacy and "happy consciousness" that Herbert Marcuse wrote about in 1964 (pp. 79, 84). Of course, the world has changed since Weiss and McGrath (1963) published their text of technological literacy and since Marcuse published *One-Dimensional Man*. Since the tragedies of September 11, there is one word to describe the type of technological literacy that engineers, technologists and the rest of us need: Rights. Constitutional rights, civil rights, and human rights, tenuous as they always are for the disenfranchised of the world, are being seriously undermined in the war on terrorism and the Bush doctrine of pre-emptive violence that accompany globalization and expansion of empire. The more the United States (USA) assumes the role of empire (Ignatieff, 2003), the more difficult the USA's Bill of Rights and international charters of human rights will be to sustain. Confrontations with fear and terror, police and military intimidation, propaganda, global expansionism, oil, and empire are dependent on the new convergences of communication, information, and medical technologies. Technological literacy in a post-September 11 context cannot be described nor understood outside of these dependencies and convergences. If it is to have any meaning at all, technological literacy must be about the value of rights, first and foremost— historically won human rights, the rights of women, worker's rights, civil rights, the rights of the downtrodden of the world, gay and

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lesbian rights, animal rights, and today, general environmental rights. This is the backdrop against which *Technically Speaking* ought to be read.

Channeled through editors Pearson and Young and the National Academy of Engineering (NAE), *Technically Speaking* is the product of nearly three years' worth of input from the Committee on Technological Literacy (TechSpeak), a group appointed through the NAE and National Research Council. The twenty members of the committee were handpicked from a range of fields including technology education (Paul DeVore and Rodney Custer). Judging by their publications, many with which I am quite familiar, the group represents right and moderate positions on the political spectrum. The few exceptions, such as Taft Broome, Jonathan Cole, Mae Jemison, and Thomas Hughes, have leaned left in their analyses of race (Broome), stratification in science (Cole), adult literacy and development (Jemison), and social history (Hughes). Of course, technological literacy is not an abstract, neutral concept; its various manifestations derive from the politics of its creators. It is this basic sociological concept that the authors of *Technically Speaking*, be it the 1963 or the 2002 version, fail to grasp. Neither literacy nor knowledge is neutral, trans-cultural, or trans-historical (Petrina, 2000a, 2000b, 2000c).

I demonstrated how derivations of technological literacy from the right of the technological literati mark commonplace manifestations in "The Politics of Technological Literacy" analysis published in 2000. In an ethical breach, this article, which TechSpeak requested for their deliberations, was not cited in *Technically Speaking*. In our current global crisis of war and rights, and as an expatriate living in Canada, there are bigger issues to take up with the committee and their version of literacy.

Chapter two of *Technically Speaking* concludes with the juxtaposition of the USA's unmatched economic and military power against the relative technological illiteracy of its citizens (pp. 70-71). The authors conclude that this is a "paradox." However, there is nothing paradoxical about it. The power of empire, the type of economic and military power currently exercised by the USA, is derived from indoctrination in the ways of capitalism, erosions and violations of basic rights, and illiteracy in the ways of political participation in science and technology. This power is derived from precisely the type of literacy that the authors of *Technically Speaking* advocate. The type of literacy TechSpeak advocates for citizens would shore up economic and military might in the USA even further (pp. 40-42). It would shore up the xenophobia necessary for empire and competitive supremacy. Hence, TechSpeak bemoans the fact that empire depends "on workers brought in from other countries." "A campaign for technological literacy could lessen our dependence on foreign workers to fill jobs in many sectors," TechSpeak asserts (pp. 5, 42). "Technologically literate citizens would be less likely to support policies that would undermine" the economy, such as regulation and curbs on free enterprise (p. 40). On the one hand, TechSpeak wants unfettered capitalism for the USA and on the other wants to increase participation, equity, and enhance the social well-being (pp. 25, 43-44). This is the double-speak of TechSpeak. These contradictory views, which I documented in my analyses of technological literacy and the Technology for All Americans project, were commonplace in the pre-September 11 era as well (2000a). "More power over foreigners without foreign dependence" is the only disposition toward economic and military might in *Technically Speaking*. Similar to the International Technology Association's *Standards for Technological Literacy*, there are no connections made between literacy and the disproportional volumes of consumption and waste in the USA, or between literacy and resignation to the dangerous arms build-up and intimidation tactics of the USA government and military across the world. A values-oriented literacy, such as that described by Michael Moore in *Stupid White Men*, would define literacy in terms of rights, sustainability, and opposition to excessive military and police surveillance.

TechSpeak advocates a values-free, fence-sitting literacy, illustrated in the three case studies of chapter two (pp. 26-36). The case studies are very well written, interesting, and if rethought, have great potential to be the types of exemplars necessary to convey a more critical technological literacy to large audiences. In these case studies and the characteristics of a technologically literate citizen that follow, TechSpeak situates literacy on the fence as a complacent, neutral practice. The case of California's energy crisis and rolling blackouts is a good example. TechSpeak's average citizen would understand a few things about electricity, evaluate a few proposals to stabilize energy markets, weigh the costs and benefits of efficiency, change a light bulb, flip a tripped circuit breaker, and turn the air conditioner down a bit at home or work (p. 36). This is already the level and activity of the average citizen and it underwrites the comfort and convenience demanded by the American dream of California. My technologically literate middle-class citizen would have the political disposition to immediately reduce personal consumption by 15%, to lobby the government for the regulation of energy production and use, and the courage to speak out against the norm when it came to energy and consumption (Petrina, 2000c; Petrina and Volk, 1993). Critical literacy would emphasize the difference between the have middle and upper classes and the have not migrant workers of California, and the activism necessary to champion citizenship and rights for the thousands of illegal immigrants at work in the Sacramento Valley. My average citizen would recognize that the wealth and massive rates of consumption of energy in the Silicon Valley and water in Los Angeles come at the poverty and thirst of millions of Mexicans to the south.

Chapters three and four are the most accurate and helpful in the book. Here, TechSpeak shifts from their troubling normative positions to descriptive analyses of surveys of technological literacy, participation rates in making technological decisions, and the institutional players in the teaching of technological literacy. While there is nothing new in these sections, the data provided will serve educators and researchers looking to embellish or support their advocacies for technological literacy. These chapters buttress the eleven recommendations that conclude the book. A top-heavy reliance is placed on the

National Science Foundation to insure the implementation of the altogether innocuous recommendations.

Technically Speaking will serve boardroom and office maneuvering for policy based on the recommendations, but at the grass roots technological literacy is about the rights of everyday people across the world. Rights for most in the USA were reduced over the last three decades to little more than property rights and the rights of consumer choice (Apple, 2002). Technological literacy has to be about more than informed consumer choice, contrary to the portrayal in *Technically Speaking*.

My recommendation is that the technological literati move themselves and literacy off the fence to attend to the interrelations between technology and rights. In the Bill of Rights of the US Constitution, the First Amendment secures the freedom for the expression of thought and opinion. It protects our most sensitive areas of personal expression: religion, ethics and political philosophy. Technological literacy would empower individuals to use the new technologies to express and inform themselves about the content and violations of rights throughout the world. This literacy would also enlighten citizens about technological threats to free speech and privacy. The Fourth Amendment protects rights to individual privacy and against the practice of arbitrary power and surveillance. The new technologies of surveillance threaten individual rights protected under the First and Fourth amendments. Satellite systems empower commercial owners and governments with the abilities to monitor and manipulate public and private activities. Data mining systems, extensively marshaled for surveillance in the post-September 11 era, provide the means to track and trail the quotidian cultural and financial activities of citizens. Remote surveillance violates common notions of privacy and one does not know anymore whether s/he is under observation. Complementary to remote sensing systems are the technologies for intimate sensing. Intimate sensing provides the government— the police, CIA, or FBI— or private companies, with the means to detect identity and monitor the use of drugs or sexual activities. Fingerprint, retinal and voice recognition, or semen, urine and DNA analysis, are just some of the new technologies that threaten Fourth Amendment rights. The power to intrude into the very core of personal autonomy and privacy is accessible to nearly anyone or any institution with the means. Invasive technologies also threaten rights protected under the Fifth, Sixth and Eighth Amendments. These amendments protect citizens accused, convicted, or suspected of crimes. The new forensic technologies offer governments incredible powers to try and predict who is and who is not a threat to national security or policing. Racial profiling, biochemical technologies, and genetics provide the incentive to identify determinants of criminal behavior and the temptation to intervene prior to the commitment of a crime (Office of Technology Assessment, 1988). Technological literacy would empower citizens to agitate for the regulation of intimate and remote surveillance and restrictions on government, police, and security.

Prior to September 11, it was easy to be complacent about mundane things like empire, literacy, security, technology and human rights. Now, we no longer have the time for complacency and we gambled away the luxury. We are all complicit in terrorism, war, the abuses of rights, and the technologies that support these activities. Literacy aside, it's time we got active and smart.

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Miscellany

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