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From the Editor

Are We There Yet?

The "are we there yet" phenomenon is familiar to most everyone. It occurs when traveling with children, especially for long distances. The question usually comes up shortly after departure and continues up until the destination is reached. The secret to reducing the phenomenon to a mild distraction is to keep the children occupied with games and other diversions, taking their minds off the length of the journey and focusing on the fun to be had "once they are there."

In our journey to reach our goals in technology education, it is easy to become so engaged in our day-to-day work that we do not realize how far we have traveled or what has happened along the way. It is comparable to how new technological developments can become a part of our everyday lives in a very short time, without us hardly realizing it. The cell phone is a prime example.

Much has happened in our field in the past fifteen years or so, but most of us must pause and reflect in order to put it all in perspective. In the US, the era started with the name change from industrial arts to technology education. The name change was followed by a flurry of efforts at all levels to articulate just what technology education is and how it might be put into teachable terms. Philosophical and practical arguments ensued in all sectors of the field. Companies began to develop "modular" approaches to technology education, defining for some just what technology education should be, *de facto*.

The US sought expertise internationally, especially from Great Britain, resulting in a miniature version of the "British Invasion" that started with the music of the Beatles a quarter century earlier. The National Science Foundation, the National Aeronautics and Space Administration, and other agencies began to offer significant funding for technology education through competitive grants. With this funding, the era culminated with the *Standards for technological literacy: Content for the study of technology* (ITEA, 2000), providing a clear idea of the parameters of the field and a substantial backbone for curriculum development. Though one could argue that the standards should have preceded the name change, that point is now moot.

While all these developments were going on in the field, a lot was transpiring externally during the same time period. New standards for mathematics and science were developed. The science standards clearly stated the importance of technological design and problem solving as a part of the study of science and technology, and there were obvious implications for technology education in the mathematics standards as well.

Corporations began to sponsor competitive events to encourage students to invent and develop new products. Though it was recently discontinued, the

Duracell Corporation and the National Science Teachers Association sponsored a technological invention contest, awarding a significant scholarship to the winner. Engineering professional associations started to become interested in what was going on with technology in the schools. Some of these organizations began to develop curriculum materials. *A World in Motion* from the Society of Automotive Engineers (SAE) is an example (www.sae.org/students/awim.htm). It is a physical science curriculum that uses (among other things) the design and building of a toy car to teach science principles. A number of professional organizations like the SAE now have professionals who are assigned exclusively to K-12 grade initiatives.

Dean Kamen, President of DEKA Research and Development Corporation, founded the FIRST Robotics Competition for high school students (www.usfirst.org). In just a few years this competition has grown to over 20,000 participants and is international in scope. Opportunities for younger students were developed through the FIRST LEGO League (www.firstlegoleague.org) as part of Kamen's FIRST Jr. Robotics program. This newer competition is growing at a rate comparable to its older sibling. Kamen, incidentally, is behind the development of the innovative Segway™ Human Transporter (HT) that has received a lot of attention in the media in recent months.

One could defensibly argue that the field of technology education, having evolved from industrial arts, has been focused upon "technological literacy" throughout its 140-plus year history. As a general education program in the schools, its philosophy has been grounded from its inception in what is good and useful for everyone. Only in the past two decades, though, have there been two parallel efforts going on at the same time to develop technological literacy: one in the field of technology education and the other outside of the field.

Initially the efforts were, for the most part, parallel but separate. This was not based on exclusivity but rather on a lack of awareness of just who the interested parties were in developing technological literacy. Through the efforts of the International Technology Education Association, the National Science Foundation, the American Association for the Advancement of Science, and others, linkages have been established to merge the parallel efforts. Most noteworthy is the significant role that the prestigious and influential National Academy of Engineering and the National Research Council had in the development of the *Standards* (ITEA, 2000). They influenced the standards so that they were useful to all those who had technological literacy on their agenda, not just those in the formalized field of technology education.

As our journey led us near to where we are right now, some intensely bright, carbon arc lamps swept the sky ahead of us. In January of this year a document titled *Technically speaking* (2002) was released amidst deserved fanfare. I cannot recall ever reading a document that presents a more logical and compelling case for technological literacy. I do not think I am being too bold in stating that everyone in the field needs to read it, including our international colleagues. It is thought provoking and sheds new light on some of the issues technology educators have philosophized about for decades.

The way in which technological literacy is to be delivered will no doubt set technology educators in the US back in their chairs. First, it defines and creates the context for technological literacy that is apart from the thinking of many in our field. Second, it recommends that technological literacy be developed by integrating it with the other subjects in the school:

> Short of the widespread adoption of dedicated courses in technology – an unlikely scenario in the committee's view – the inclusion of technology subject matter in other academic areas is one of the surest ways of increasing the visibility of technology in U.S. schools (p. 104).

This assertion was supported by citing the recent Gallup poll on technology that was commissioned by the ITEA:

> Ninety-seven percent [of the poll respondents] said they believed the study of technology, broadly defined, should be part of the school curriculum; two-thirds said it should be integrated in other subjects rather than taught as a separate course (p. 66).

At the same time, *Technically speaking* recognizes the work of technology educators throughout the document and it amply cites the *Standards for technological literacy*. It also indicates that technology educators will have an important role in infusing technological content throughout the school curriculum: "Teachers who specialize in technology, still relatively few in number, will be essential to a serious effort to boost technological literacy" (p. 7).

Clearly, a new paradigm for technological literacy is unfolding – a paradigm that is quite different from the one prompted by the name change that occurred nearly two decades ago. Just what role our teachers and the "dedicated courses in technology" they are now delivering will have in this new paradigm is neither explicit nor implied in *Technically speaking*. Perhaps this was by design, rightfully allowing the technology education profession itself to define its role in the new paradigm. Whatever the case, such an effort must begin at once. One thing is for certain: We are not there yet!

JEL

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Articles

Thai Students' Attitudes and Concepts of Technology

Kurt H. Becker and Somchai Maunsaiyat

Introduction

Of the eight major programs mentioned in Thailand's Eighth National Education Development Plan (1997-2001), one is aimed at developing human capability in the areas of science and technology. This is to address the fact that the teaching of technology in Thailand is lagging behind the technological changes of the last decade. Part of this reform effort is the development of conceptual based learning activities in science and technology for 12 to 15-year old students. These concepts are being introduced through the offering of a subject at the high school level. de Klerk Wolters (1989) indicated learning the concepts of technology is necessary and should be required for all students of this age range. Cross and McCormick (1986) added that students in both primary and secondary schools need to learn to solve technological problems in creative ways. Students also should understand the nature of technology. Understanding technology is just as important for Thai students as it is for students in other countries.

In order to develop a student's technological literacy, de Klerk Wolters (1989) suggested that it is important to take into account pupils' interests, opinions, and needs when developing technological curriculum. An understanding of students' knowledge of and attitudes toward technology is necessary and prerequisite to effective teaching about technology (Bame, Dugger, de Vries, & McBee, 1993). These concerns led to the development of the Pupils' Attitude Towards Technology (PATT) project. The first Pupils' Attitude Towards Technology project was established by Jan Raat and Marc de Vries in 1984 at the University of Technology in Eindhoven in the Netherlands. The main purpose was to assess what attitudes students, aged 11 to15, had toward technology.

It became evident through the PATT research that the students had incomplete and vague concepts of technology. There also appeared to be great differences between boys and girls in their attitudes toward technology. Since this beginning, the PATT research has been conducted in over 22 countries,

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including the PATT-USA study conducted by Bame and Dugger in 1990. In 1993, a shortened version of the PATT-USA instrument was developed by Jeffrey. This Technology Attitude Scale (TAS-USA) instrument was intended for use by American teachers at the middle school level to determine the students' attitudes toward technology.

Based upon the literature, the researchers in this study believed that an assessment of the attitudes and understanding of technology among students was necessary before technology curriculum reform in Thailand could begin. Teachers, administrators, parents, curriculum developers, and students would all benefit from such an assessment. Thus, there was a clear rationale for conducting a PATT study in Thailand.

Purpose of Study

The purpose of this study was to develop a Technology Attitude and Concept Scale (TACS-Thai) instrument by translating and validating the revised TAS-USA instrument. The instrument developed in this study was used by Thai teachers at the secondary school level to determine the attitudes and concepts of technology among 12 to 15 year-old students in the Bangkok metropolitan area. The specific objectives of this study were:

1. To develop the TACS-Thai instrument by adaptation of the TAS-USA and the PATT-USA instrument.
2. To develop a Thai version of the Technology Attitude and Concept Scale (TACS) by translating the US version.
3. To validate the TACS-Thai instrument for use by Thai teachers at the secondary school level. This included the determination of appropriate language and word usage within the instrument through the use of a pilot study.
4. To analyze each section of the TACS-Thai through a panel of experts and statistical analysis.
5. To provide comparisons between PATT-USA and TACS-Thai studies.
6. To provide the recommendations for the improvement of developing the TACS-Thai instrument.

Methodology

The Technology Attitude and Concept Scale (TACS-Thai), an adaptation of the Technology Attitude Scale (TAS-USA) and the Pupils' Attitudes Towards Technology (PATT-USA), was used to collect data in the study. The adaptation of both original instruments maintained consistency with the original design in that the purpose was descriptive, "...the instrument is not a test instrument but a descriptive instrument" (Ratt, 1992, p.31).

The general procedure followed to validate the TACS-Thai instrument consisted of the following:

1. Present the translation of the instrument to a panel of experts to examine for appropriate language, clarity and brevity.
2. Modify statements on the instrument according to the suggestions from the panel of experts.

3. Conduct a pilot study to determine if the directions, statements, time to complete the instrument, and analysis of data were conducive to continuing the validation process.
4. Complete analysis of the data for reliability using Cronbach's alpha coefficient for homogeneity on the attitude scale and the Kuder-Richardson formula 20 (KR-20) on the concept scale.
5. Interpret the analysis of data as it pertained to validation of the instrument.

Instrument

In the mid-1980s researchers in the Netherlands initiated a large-scale study to determine what pupils' attitudes and concepts were regarding technology. The Pupils' Attitudes Towards Technology (PATT) instrument was a result of this research effort that soon spread to several other countries. Bame, Dugger, de Vries, and McBee (1993) conducted a large-scale research study on attitudes towards technology in the United States, resulting in the PATT-USA, that reported over 10,000 responses from students between the age of 13 and 15 who were enrolled in technology education/industrial arts classes from seven states. The instrument incorporated a Likert scale for measurement and consisted of 100 items.

In 1987, the Technology Attitude Scale (TAS) instrument was developed from the large-scale PATT-USA research. The three-part TAS instrument was designed specifically for use by classroom teachers to determine students' attitudes towards technology and concepts of technology. In 1993 the TAS instrument was adapted and validated by Jeffrey for use by American teachers at the middle school.

The first section of the TAS was designed to obtain demographic information about the respondents. The second section, the attitude scale, was designed to obtain information about students' attitudes towards technology through the use of 26 expressions, or items, divided over six subscales. Respondents completed the attitude scale by specifying to what extent they agreed with each statement by using a five choice Likert scale: strongly agree, agree, neutral, disagree, and strongly disagree.

The third section of the instrument, the concept scale, was designed to obtain information about the students' concepts of technology, utilizing 28 items divided over four subscales. The conceptual section measured the cognitive or knowledge aspects, based on five generally accepted characteristics (de Vries, 1987) of the concepts of technology. The concept scale measured the knowledge and concepts of technology at a relatively abstract level. Students responded to the concept scale by indicating Agree, Disagree, and Don't Know.

The TAS-Thai instrument was adopted from the TAS-USA instrument. It consists of 63 items or statements that cover both attitude and concept scales. There are 26 items divided over six subscales in the attitude scale. The subscales of the attitude scale include: *interest* (five statements), *role pattern* (four statements), *consequences* (five statements), *difficulty* (three statements), *curriculum* (four statements), and *career* (five statements). There are 28 items divided over four subscales in the concept scale. The subscales of concept scale include: *technology and society* (10 statements), *technology and science* (six statements), *technology and skills* (seven statements), and *technology and pillars* (five statements).

The first section of the instrument (nine items) was designed to obtain demographic information about the respondents. This included gender, age, grade level, involvement with technology education (present or previous enrollment in a technology education class), parents' occupations, and the nature of the technological environment at home. These questions were not included in the original TAS-USA. The newly designed instrument was then translated into the Thai language and was validated and tested for reliability.

Instrument Validity and Reliability

The TAS-USA instrument developed by Jeffrey (1993) was determined to be valid and reliable. The content validity was established though the utilization of a panel of experts. The reliability correlation values for the attitude scale were obtained through the statistical application of Cronbach's homogeneity coefficient alpha. An alpha-value of at least .60 was set for the acceptance of the TAS. The reliability estimates for the concept scale were obtained through the statistical application of the Kuder-Richardson formula 20 (K-R 20) to obtain internal consistency values.

In the large group study in the US (n = 183) an overall alpha coefficient of .81 was found on the attitude scale and an overall reliability coefficient of .83 for the concept scale (Jeffrey, 1993). Therefore, the content validity and reliability of the TAS-USA instrument were considered to be acceptable for use in measuring students' attitudes and concepts of technology.

In developing the TACS-Thai instrument from TAS-USA, five additional items about demographics of students were added. A panel of experts was used to establish content validity for the TACS-Thai instrument. Members of the panel were selected because of their experience in translating the English language into the Thai language, expertise in instrument development, and expertise in the use of statistics. An English teacher from the Department of Social Studies and Language, King Mongkut's Institute of Technology Ladkrabang (KMITL), was selected to be a member of the panel. Two individuals from the Supervisory Unit in the Department of General Education with knowledge and experience related to secondary school students and secondary school curriculum were also selected to serve on the panel of experts. In addition, the instrument was reviewed by a professional statistician from the Office of Graduate Studies, KMITL, and a professor from the Department of Measurement and Evaluation, Faculty of Education, Srinakharinwirot University, to insure that the format of the instrument and data were acceptable for statistical analysis. The panel examined all translated statements for appropriate language and word usage and made suggestions about item terminology to enhance clarity and conciseness. This procedure was consistent with Ary, Jacobs, and Razavieh (1985) regarding content validity: "In order to obtain an external evaluation of content validity, the test maker should ask a number of experts or other teachers to examine the test content systematically and evaluate its relevancy to the specified universe" (p. 215).

Ary, et al. (1985) also described reliability as the "degree of consistency with which an instrument measured what it is supposed to measure." The Cronbach alpha procedure was used to obtain the reliability estimate of the internal consistency of the attitude measurement section of the TACS-Thai. McDaniel (1994) suggested that "the Coefficient Alpha is a suitable procedure to use when responses get a specific value as in an attitude scale where responses range from strongly agree to strongly disagree" (p. 64). Mueller (1986) also mentioned that "tests with items scored along a continuum, such as Likert scale attitude items (scored 1 through 5), require the use of Alpha" (p. 61).

van den Bergh (1987) stated that, "an Alpha-value at least more than .60 indicates a good reliability of scale " (p. 43). Therefore, an alpha-value of at least .60 or higher was the target number set as a goal for the acceptance of the TACS-Thai.

The Kuder-Richardson Formula 20 (KR-20) procedure was used to obtain the reliability estimate of the internal consistency of the concept measurement section of the TACS-Thai instrument. The Kuder-Richardson Formula 20 is "probably the best known index of homogeneity . . . and is based on the proportion of correct and incorrect responses to each of the items on a test" (Ary, et al., 1985, p. 233). McDaniel (1994) mentioned that Kuder-Richardson is a form of coefficient alpha that is applicable when items are scored as "right" or "wrong" (p. 52). The concept measurement section of the TACS-Thai was scored using a dichotomous procedure (Correct = 1; Not Correct or Don't Know = 0).

The TACS-Thai Pilot Study

In an effort to test the appropriateness of the language and word usage in the TAC-Thai instrument, along with a determination of its validity and reliability, a pilot study was conducted. The students selected for the pilot study were not included in the main study. The pilot study sample consisted of 80 secondary school students at Panyaworakun School, Nongkham, Bangkok. There were 34 boys (42.5 percent) and 46 girls. Their age ranged from 13 to 15 years. Most of them were age 14 (72.5 percent). All of them were in the eighth grade. Thirty two students (40 percent) had taken a course in technology education. Eighty percent of the pilot study sample had technical toys at home. Only 24 (30 percent) of 80 students had a technical workshop at home. Eighteen students (22.5 percent) had a computer at home.

In addition to completing the instrument, the students were asked to circle any words they did not understand and to indicate any difficulties they had in completing the instrument. Modifications to the instrument were made with consideration given to the original intent of the instrument with the guidance of the panel of experts.

The alpha coefficient values for the attitude scale of the pilot study are summarized in Table 1. As shown in Table 1, the alpha coefficient of two subscales (subscale 2, ∝ = .66 and subscale 6, ∝ = .62) exceeded the minimum .60 alpha value criterion. The alpha of subscale 5 (∝ = .57) was very close to the minimum criterion. The other three subscales (subscale 1, ∝ = .32; subscale 3, ∝ = .32; and subscale 4, ∝ = .14) did not meet the criterion. However, the overall correlation alpha for all subscales (∝ = .74) exceeded the minimum .60 value.

Table 1
Alpha Values of Attitude Scales in Pilot Study

Subscales		∝
1	Interest	.3217
2	Role Pattern	.6609
3	Consequences	.3164
4	Difficulty	.1440
5	Curriculum	.5746
6	Career	.6227
	Overall	.7380

Table 2 shows the values of the alpha coefficient for the concept scale of the pilot study. Two of the four subscales (subscale 1, ∝ = .51 and subscale 2, ∝ = .51) were close to the minimum .60 value indication. The alpha of subscale 3 (∝ = .38) and subscale 4 (∝ = .36) did not meet the minimum value. However, the overall alpha of all subscales (∝ = .72) did meet the criterion value. In consultation with a professional statistician, the researcher made the decision to proceed with the administration of the TACS-Thai instrument to the primary sample.

Table 2
Alpha Values of Concept Scales in Pilot Study

	Subscales	∝
1	Technology and Society	.5073
2	Technology and Science	.5087
3	Technology and Skills	.3827
4	Technology and Pillars	.3642
	Overall	.7219

Subjects

The accessible population for this study consisted of the lower secondary school students from one private school and three public schools in the Bangkok metropolitan area. These schools operate under the Department of General Education. The selected schools were recognized as leaders in providing technology education because they had a technological environment and students were engaged in technology-related activities such as the School-Net project, which provided more opportunities to use modern technology.

The sample in this study consisted of 616 students enrolled in the four secondary schools mentioned above. Specifically, the schools were Saint Mary College (private rural, *n* = 177), Protpittayapayat School (public rural, *n* = 147), Panyaworakun School (public rural, *n* = 150), and Prakhanong Wittayalai School (public urban, *n* = 142). This sample was considered to be representative of the whole population of the four selected schools with respect to sex, gender, grade, geographical variations, and school types. A sample size of at least 400 students was selected according to the suggestion of Krejcie and Morgan (1970, p. 211), who stated that "with the given population sizes of 100,000, a sample size of 384 is required." In addition, Gay (1996) suggested that "beyond a certain point (about 5,000), the population size is almost irrelevant and a sample size of at least 400 will be adequate" (p. 125).

According to Ary, et al. (1985), stratified sampling can be used when the population contains a number of subgroups or strata that may vary in the characteristic being studied (p. 142). Stratified sampling, according to Ary et al. (1985), ensures that each class of the population was adequately represented in the sample. Because this study included secondary school students in the seventh, eighth, and ninth grades from selected schools in the Bangkok metropolitan area, a stratified sampling was used.

Data Collection

The TACS-Thai instrument was delivered by the researcher to the coordinating teachers with instructions. The instrument was then administered to the sample students in random classes in the seventh, eighth, and ninth grades of each selected school. Individual instruments were hand scored and analyzed through the Office of Graduate Studies, Faculty of Industrial Education, KMITL.

Data Analysis

The instrument was analyzed by means of the statistical analysis package SPSS/PC+. Principal analysis procedures included the calculation of descriptive and frequency statistics of the data. Cronbach's homogeneity coefficient alpha was employed to determine the reliability and internal consistency of the attitude measurement section of the instrument. The Kuder-Richardson Formula 20 was used to determine the reliability and internal consistency of the concept measurement section of the instrument. Consultation was sought from a statistician familiar with the software and social research while preparing the data for processing and analysis.

Results

Findings of the Large Group Administration

The main administration of the TACS-Thai involved 292 boys and 324 girls at the four selected secondary schools in Bangkok, Thailand. The ages of the students ranged from 11 to 16 years in seventh, eighth, and ninth grades. Of 616 students completing the TACS-Thai instrument, 73.4 percent (452) had completed a technology education class.

Technological Climate in the Home

Five questions were asked to assess the technological climate in the home. These dealt with the student's perception of the technical nature of their parents' jobs and the presence of technical toys in their home. These findings are detailed in Table 3.

Table 3
Technological Climate in the Home

Category	*n*	%
Extent father's job has to do with technology		
Very Much	21	3.4
Much	129	20.9
Little	164	26.9
Nothing	280	45.5
Extent mother's job has to do with technology		
Very Much	14	2.3
Much	75	12.2
Little	146	23.7
Nothing	363	58.9
Technical toys in the home		
Yes	543	88.1
No	73	11.9
Technical workshop in the home		
Yes	202	32.8
No	407	66.2
Personal computer in the home		
Yes	108	17.5
No	507	82.3

About one fourth of the students (24.3%) believed that their father's job had "much" or "very much" to do with technology. Only 14.5 percent of students believed their mother's job had very much or much to do with technology. Over one half of the student's (58.9%) believed that their mother's job had nothing to do with technology. A large majority (88.1%) of the students indicated that technical toys were present in their home. Only 32.8 percent indicated the presence of a technical workshop in the home. Slightly less than a fifth (17.5%) indicated there was a computer at home.

Cross Comparison of Demographics

Gender differences were explored relative to the demographics section of the instrument. A summary of the findings are shown in Table 4 and may be summarized with the following statements:

1. *Gender and Age*: The girls tended to be younger than the boys. That is, there were proportionally more girls who were 13 or younger than there were boys, and there were proportionally more boys than girls who were 15 or older.
2. *Gender and Grade Level*: Almost one third of the boys and girls were in each grade level.
3. *Gender and Home Environment*: Girls tended to rate the father's job as less technical in nature than did the boys. That is, 73 percent of the girls, compared to 70 percent of the boys, rated their fathers' job and having "Little" or "Nothing" to do with technology. Girls tended to rate the mother's job as less technical in nature than did the boys. That is, 84 percent of the girls, compared to 81 percent of the boys, rated their mothers' job and having "Little" or "Nothing" to do with technology. The existence of technological objects, such as toys, workshops, and computers was viewed as an indicator of how technological the home environment was. For all such indicators, a greater proportion of boys than girls perceived their home as technological.

Three attitude subscales (*general interest in technology, gender difference, and consequences of technology*) were selected to compare to the results in the US study. To determine if the demographic characteristics had any effect on attitudes toward technology, analyses of variance (ANOVAs) was used (see Table 5 and 6).

The relationship of demographic characteristics to attitudes toward technology can be summarized as follows:

1. The gender of the students had a significant effect on all attitude subscales. The reader is reminded that a lower scale value represents a more positive attitude. Boys (mean = 2.32) indicated a greater interest in technology than girls (mean = 2.45), and girls (mean = 1.98) rated technology as having a more positive consequence than did the boys (mean = 2.05). In addition, there was a significant difference between boys and girls on their attitude toward gender differences regarding technology. Girls appeared to view technology as an activity for both genders more than boys did. No significant effect of grade level on general interest in technology or the consequences of technology was found. However, the gender differences of the ninth grade level students were significantly greater than those of students in the lower grade level.
2. The extent to which a student's father was reported as having a job dealing with technology was significantly related to only one of the three subscales, Gender Differences. The differences attributed to the technological nature of

   a father's job on the attitude scale and Technology is an Activity for Both Girls and Boys, were not linear. Those students reporting "Little" (mean = 2.56) or "Much" (mean = 2.50) viewed technology as an activity for both sexes significantly more than students who reported “Very Much” (mean = 2.86).

Table 4
Cross Comparisons of Gender with Student Characteristics and Home Environment.

	Boys		Girls	
	n	%	*n*	%
Age of students				
12 or younger	58	19.86	96	29.63
13	107	36.64	109	33.64
14	98	33.56	101	31.17
15	26	8.90	17	5.25
16 or older	3	1.04	1	0.31
Grade in school				
7th	97	33.22	116	35.80
8th	100	34.25	100	30.86
9th	95	32.53	108	33.34
Extent father’s job has to do with technology				
Very Much	16	5.48	5	1.54
Much	61	20.89	68	20.98
Little	71	24.32	93	28.70
Nothing	135	46.23	145	44.75
Extent mother’s job has to do with technology				
Very Much	11	3.77	3	0.93
Much	32	20.89	43	13.27
Little	74	25.34	72	22.22
Nothing	163	55.82	200	61.73
Do you have technical toys at home?				
Yes	268	91.78	275	84.87
No	24	8.22	49	15.13
Is there a technical workshop in your home?				
Yes	111	38.01	91	28.09
No	239	81.85	268	82.72

3. The number of students’ mothers who had jobs dealing with technology was significantly related to only one of the three subscales, Gender Differences. Results pertaining to the subscale, Technology is an Activity for both Girls and Boys were not evident. The significant difference was between those reporting “Much” or “Little” and those reporting “Very Much.” The former group viewed technology as something for everyone, regardless of sex, to a significantly greater extent than did the latter group.
4. Having technical toys at home, having a technical workshop at home, or having a personal computer at home did not seem to make a difference in students’ attitudes toward technology.

5. Taking or having taken industrial arts or technology education courses made a significant difference on all attitude subscales except the Technology is Difficult scale. Such course experiences also made a difference on the Technology and Society concept scale. Students who had taken technology classes displayed greater knowledge about technology than did students who had no exposure to the classes.

Table 5
Results of One-Way ANOVAs on Grade, Father's Job and Mother's Job

Characteristics	General Interest in Technology	Gender Differences	Consequences of Technology
7th	2.33	2.63	2.06
8th	2.44	2.73	2.00
9th	2.40	2.56	1.98
Significance		*	
Extent father's job has to do with technology			
Very much	2.25	2.86	1.93
Much	2.33	2.50	1.95
Little	2.41	2.56	2.06
Nothing	2.43	2.72	2.01
Significance		*	
Extent mother's job has to do with technology			
Very much	2.30	2.98	1.91
Much	2.26	2.43	1.87
Little	2.40	2.53	2.06
Nothing	2.43	2.70	2.02
Significance		*	

* alpha significance <= .01

Comparisons Between the Results from the PATT-USA and TACS-Thai Studies

Overall, Thai students had lower mean scores in the general interest in technology subscale, implying that they had a higher general, overall interest in technology. This greater interest was maintained as well when the Thai students were sub-grouped according to the variables of the study.

Overall, US students had lower mean scores in the gender difference subscale, implying that they regarded technology as an activity for both sexes more than did their Thai counterparts. The means of the subscale on the consequences of technology were nearly the same for both US and Thai students, implying similar opinions on the importance of technology in the world in general. Again, this equivalence was maintained when the comparisons were made by subgroup.

As indicated in Table 7, students in both the United States and Thailand are interested in technology. The comparison shows that boys are more interested in technology than are girls in both countries. Students in both Thailand and the

US think that technology is a field for both girls and boys. However, girls are even more convinced of this than are boys. Other similarities include:

1. In the Thailand study a positive influence of a parents' technological profession on the student's attitude was found, the same as the PATT-USA study.
2. As in the US study, it was found that Thai students' understanding of the concepts of technology increased with age.
3. The gender of the students had a significant effect on the attitude subscales of Interest, Role Pattern, and Difficulty in both countries.
4. Both Thai and US boys had a similar score on the concept items, whereas Thai girls (mean = .50) have a higher understanding of the concepts of technology than US girls (mean = .67).

Table 6
Results of One-Way ANOVAs On Demographic Characteristics

Characteristics	General Interest in Technology	Gender Difference	Consequences of Technology
Gender			
Boy	2.32	2.93	2.05
Girl	2.45	2.37	1.98
Significance	*	*	*
Have technical toys?			
No	2.47	2.71	2.03
Yes	2.38	2.64	2.01
Significance			
Have workshop at home?			
No	2.42	2.64	1.98
Yes	2.32	2.63	2.08
Significance			
Have personal computer?			
No	2.37	2.63	2.01
Yes	2.47	2.64	1.98
Significance			
Are you taking or have you taken TE/IA			
Done	2.35	2.56	1.95
Taking	2.34	2.60	2.02
Never	2.50	2.80	2.14
Significance	*	*	*

*alpha <= .01

Table 7
Boys' and Girls' Scores on the Attitude and Concept Scales

		Interest	Pattern	Role Consequence	Difficulty	Curriculum	Career
Thailand (Bangkok)	Boys	2.32	2.93	2.05	2.04	2.17	2.40
	Girls	2.45	2.37	1.98	1.79	2.17	2.48
		*	*		*		
United States	Boys	2.50	2.30	2.00	2.70	-----	-----
	Girls	3.00	1.70	2.10	2.40	-----	-----
		*	*		*		

Concept Scales		Technology & Society	Technology & Science	Technology & Skills	Technology & Pillars	Total Scores
Thailand (Bangkok)	Boys	.57	.45	.50	.53	.51
	Girls	.58	.42	.49	.52	.50
United States	Boys	-----	-----	-----	-----	.50
	Girls	-----	-----	-----	-----	.67

* alpha <= .01

Conclusions

The overall conclusion of this study is that the Technology Attitude and Concept Scale for Thailand (TACS-Thai) is a valid and reliable instrument overall. The adaptation of the TACS-Thai instrument from the original TAS-US instrument and the translation from English to Thai was successful. The overall reliability estimate of the six attitude subscales in the pilot study was .74 and the overall reliability estimate of the concept scale was .72. It was concluded that the pilot study's attitude scale and concept scale had acceptable combined reliability. The content validity of the large group administration as judged by the panel of experts, the overall alpha value of .74 for the attitude scale, and the overall reliability estimate of .64 for the concept scale indicated that the TACS-Thai instrument could be used to ascertain the attitude towards and concepts of technology of secondary school students in Thailand. The TACS-Thai should be useful to Thai teachers, program planners, curriculum developers, and administrators at the secondary school level in Thailand.

These were differences in students' attitudes toward technology between the United States and Thailand. The differences can be attributed to culture and the educational system, especially the teacher-centered methodology used in the Thai classroom contributed to these differences. Overall, the patterns of attitudes and concepts of technology among the US and Thai students were similar based on the results of this study.

Recommendations

The results of this study suggest additional directions for consideration in future research. The following recommendations are offered.

1. It is recommended that an expanded number of secondary schools in Thailand be included in future research. As a basis for comparison of

students' attitudes and concepts toward technology in different areas, it is recommended that future research expand the population of interest to include other cities in Thailand.

2. It is suggested that future research include the development of an upper secondary school TACS instrument and an elementary school TACS instrument. The research would help to determine the appropriateness of technology curriculum at the upper secondary school level and for learning reinforcement and technological awareness at elementary school level.
3. It is recommended that the scoring procedures of the instrument and an instruction manual for the teachers be developed. This instrument should be valuable for use by classroom teachers. The TACS-Thai instrument needs to be developed into a useable form, including instruments for administration, scoring, and analysis of results.
4. Future PATT researchers who want to translate and validate a Technology Attitude Scale for use in other countries should pay attention to the importance of language and culture of that specific country in order to be successful.
5. High school students in Thailand should take more technology education courses in order to help them learn more about technology and have more logical attitudes toward technology.

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Design Technology in the Elementary School—A Study of Teacher Action Research

Janice Koch and M. David Burghardt

This article addresses the effects of requiring action research projects in the education of classroom teachers as mandated by a graduate program in elementary education. The Master of Arts Program in Elementary Education with a specialization in Mathematics, Science and Technology (MST), is designed for experienced elementary school teachers who seek the skills and knowledge, and attitudes and dispositions, to integrate the teaching of these areas. Technology is defined as *design technology* (DT), which encompasses the study of the technological world that inventors, engineers, and other innovators have created. It includes within it *information technology*, the integration of skills that require the use of computer applications to enhance student learning of mathematics and science.

Design technology is applied to the study of elementary science and mathematics to enhance and deepen elementary school students' conceptual understandings in these areas. Elementary school teachers are required to create and implement a unit centered on design technology that demonstrates connections among mathematics, science, and technology in their classrooms. They are then required to conduct research in their classrooms to examine the effects of implementing this unit on student learning, attitudes, and dispositions, as well as on their personal professional development.

This graduate program requires that the action research initiative be documented as a culminating experience through the writing of the Masters Thesis. This interdisciplinary Masters Program challenges elementary school teachers to integrate mathematical analysis, scientific inquiry, and technological design (DT) in multiple curriculum areas. Elementary school students who are engaged in units centered on design are involved in project based learning where they are using science and or mathematics concepts to design and construct a solution to a problem. DT integration is a vehicle for engaging students in their own thinking and problem solving by giving them the opportunity to direct their own learning. This paper addresses the effects of requiring teachers to use

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Design Technology with their own students and the effects of engaging teachers in research in their own classrooms.

Design Technology Connecting Mathematics and Science

While many teacher education programs integrate science and mathematics, few have added the component of design technology to the preparation of elementary school teachers; in New York State only two programs do so (NYSED, 2000). We address how the use of design challenges in their classes helped teachers give students more control of their own learning, hence, shifting their thinking about the role of the classroom teacher. Many educators talk about integration across the disciplines but at times the standards-based movement forces them to be more discipline based. "No matter what the content, we can design active linkages between fields of knowledge. An interdisciplinary approach to learning may be seen as a curriculum approach that *consciously* (italics added) applies methodology and language for more than one discipline to examine a central theme, problem or experience" (Jacobs, 1989). This is an appropriate description of an elementary grades DT unit that sets out to explore a mathematics or science topic and then to intentionally connect concepts from these disciplines to a design problem.

As the *Standards for Technology Literacy* (ITEA, 2000) note, becoming literate in the design process by acquiring the cognitive and procedural knowledge to create a design also has the potential for enhancing the students' understandings of the science and or mathematics concepts. One such example would be the design and construction of a model house for researchers in the heart of the rainforest. This house would need to occupy the least amount of surface area to make the smallest impact on the forest floor. In the actual rainforest, land is conserved when the houses are built on stilts and the house itself occupies the space between the floor and the canopy. By engaging students in designing an appropriate model for the rainforest, they apply their understanding of the constraints of the rainforest environment. In another DT unit on the human body, second graders designed and built a model skeleton with moveable joints. They needed an understanding of the ways in which joints operate to make a credible model. A deep understanding of the mathematics or science concepts is required for the students to engage in design and construction (ITEA, 2000, p.46).

Research addresses the importance of hands-on activities which, supported by meaningful discussion and theory building (Brooks and Brooks, 1993), help students construct meaning. Further, when students are encouraged to create artifacts (Appleton, 2000), they both reflect and enhance student understanding.

A constraint of the classroom research program described here is the required time frame. The students implement the integrated unit and do the research in the span of one semester. They are guided by two professors who visit with them in their classrooms as co-teachers and consultants. The students/classroom teachers are limited by needing to select a unit that is congruent with the elementary school curriculum dictated by their school, grade level, and district.

What we have learned is that the very process of implementing a project-based DT unit, gathering data about it, and reporting their findings has had a profound impact on the teachers. This is consistent with the research on teacher inquiry or "action research" (Cochran-Smith and Lytle, 1999) which reveals that the teacher-researcher transforms herself as she knows and better understands her classroom and the process of teaching by inquiring into them. *In the On-Line Journal for Teacher Research* (2000), teachers reflect on the ways in which the process of inquiry has been professionally and personally transformative. "Teacher-research as an intentional and systematic study of our own classrooms and schools, is an emergent approach to study – *in situ* - and by the insiders – the educational phenomena taking place in the schools and classrooms. This approach is an *inside out* way of producing educational knowledge; that is from inside the schools and classroom"(Fischer, et al, 2000).

What distinguishes this teacher-research initiative is that it is mandated by academia, but implemented by the classroom teacher. The support of and guidance for teacher research yields valuable data for the field. This paper explores the following aspects of this DT-based teacher research initiative:

- The impact of classroom research to support the development of reflective practitioners;
- What teacher-research in DT reveals about student' abilities to direct their own learning;
- How interdisciplinary design-based projects engages students with special needs in a heterogeneous classroom.

Hence, this paper explores both the effects of a graduate program mandating teacher research and the effects of doing teacher research in the context of integrating design technology.

Framing the Conditions for Teacher Research

"Mathematics, Science, and Technology Education in the Elementary School," the culminating course in the MA/MST degree program, requires teachers to conduct an action research investigation in their own classroom. They are mentored through this experience by the co-authors, meeting weekly as a cohort, as well as having one-on-one meetings. At the beginning of the course, with the guidance of the course professors, the teachers create a unit, centered on design technology, which addresses conceptual understandings in mathematics, science, language arts, or social studies. In developing the unit, the teachers reflect many facets of their graduate education – e.g., learning outcomes, assessment strategies, diversity issues, connections to standards – to create a coherent unit that fits with each school's curriculum. As they are teaching the unit, they are writing their master's thesis, documenting their classroom research through several types of data collection.

The expectation is that each graduate student/classroom teacher will implement an integrated unit that addresses an elementary curriculum topic by requiring their students to be engaged in design technology and related mathematics and/or science concepts. This integrated unit needs to be linked to local frameworks and reflects the culture of the geographic community in which the school is situated. After developing this unit, and before implementing it, teachers are asked to assess students' prior knowledge as well as their attitudes toward math and science. These baseline data provide meaningful information for the teachers and help them to assess student change by the completion of the unit.

For the research report, each teacher/graduate student is required to complete a six-part Masters Thesis that includes:

- A description of their setting and students;
- A review of the literature related to their topic;
- A plan for analyzing their students' attitudes and content knowledge, before and after implementing the unit;
- A description of the experience of implementing the unit for themselves and their students;
- An analysis of their data;
- Conclusions and Implications.

The teachers maintain a daily teaching journal, which serves as an important source of data as they describe the experience of teaching the unit. The professors maintain their journals about each teacher's research and use their final thesis publication as a source of data.

The professors provide support through weekly meetings, daily email communication, special conferencing, and visits to the classrooms. The following quote comes from a new first grade teacher implementing a DT unit about the seashore:

> I am less nervous with the daily lessons because my students have taken ownership and are quite interested. I am just nervous that we are not going to be able to study all the areas planned. Is that ok? Measurement has popped up as students attempted to describe a horseshoe crab. Living and non-living came up again. Students mostly associate living with humans. I am looking for suggestions on how to open this up a bit. I ask myself what should I expect from first graders? Should I be surprised like everything else?

Teacher research, also called action research or classroom research, is fraught with misinterpretations (Feldman & Minstrell, 2000). This project proceeds under the assumption that teachers who study the implementation as a long term unit with their students by collecting data, keeping a daily journal, describing the experience, and analyzing their data, and finally writing about it, are engaged in research. The program described in this paper mandates this form of classroom research.

The Design Challenge

"Technology Education in Elementary School," is one of the key courses in the MA/MST program. It introduces teachers to the field of technology education. A goal of the course is for teachers to become knowledgeable about and to use the design process. In the context of learning about design through activities and projects, other goals are achieved as well. Teachers become familiar with tools, resources, and materials that are available and can be used in an elementary school classroom. They use a design portfolio that guides and documents student work and thought, and they learn how to adapt it for a particular unit. Importantly, the teachers develop strategies to authentically assess student work based on the design process and the portfolio by using critiques of their own design projects and portfolios. Finally, they create activities with design at the heart that reflect an understanding of concepts in mathematics, science, and social studies.

Integrating design technology in elementary school and linking it to math and science is a vehicle for enhancing student learning in mathematics and science. Inherent in the design process is the problem to be solved that must perform certain tasks or meet certain specifications. The design challenge is limited by constraints such as materials available, time, and resources. When elementary students are required to meet design challenges, it encourages their individuality and critical thinking, and honors their own ideas. The presentation of the final product requires that students defend their ideas and therefore integrate their conceptual understanding of mathematics, science, and technology. For example, students are asked to report why they chose their specific design solutions and how they went about creating them.

As the teachers develop appropriate design challenges for their students, they are guided by the following question, "How does the design project enhance the students' understanding of mathematics and or science?" They are also guided by the ways in which they will assess what the students know and are able to do as a result of engaging in the design project. For example, one teacher implemented a unit on human body systems in the second grade. At various points in this unit, the children were asked to design and construct models of body systems using available materials. The chest vest consisted of a large paper bag with a hole on top for the children's head to peek through and armholes for each arm. Attached to the bag were three-dimensional models of the organs found inside the chest cavity. When the children wore their "vest" they were asked to describe each organ and its function. The students talked about why the organs were situated where they were. This design project presentation was assessed with the use of a rubric that guided both the evaluation and the student performance. This type of embedded assessment is typical for design projects.

Analyzing Teacher Projects

The source of data for this study was forty completed masters theses that documented the experience of using design technology with elementary school students. The following research questions were addressed. As result of implementing this unit:

1. What changes, if any, did classroom teachers find in their students' attitudes towards mathematics, science, and technology?
2. What changes were noticeable in their own practice?
3. What emerged from the teachers' analysis that could be useful for informing future practice?

The analysis of these theses conformed to standard practice for data analysis, involving systematically searching through the sections of the text, organizing ideas, breaking them down into manageable units, and searching for patterns (Bogdan & Biklen, 1992). Interpreting and making sense of these teacher-authored documents involved giving special attention to parts four, five, and six of the Masters Theses where teachers documented the experience, the results of their assessments, and the implications for future work using design technology. Searching through these sections of the forty Masters Theses revealed three significant coding categories. These are a means of sorting the descriptive data that led to the emergence of three important themes that were revealed consistently throughout the teachers' theses.

These themes included (1) changes in teachers' own perceptions of their abilities to create student centered classrooms where each student group has control of the direction of their learning; (2) changes in students' attitudes towards mathematics, science and/or technology and in their understanding of the materials relating to the design process; (3) changes in the ways in which children with special needs engaged in group work and contributed to the final design project.

Working with a research assistant, we checked our data against an outside reader's and asked her to quantify the number of times each theme was mentioned in the forty theses. Out of the forty analyzed theses, thirty-eight teachers reported experiencing a shift in their teaching practice resulting in their changing perceptions of their role as teachers. Forty reported significant changes in student attitudes and comprehension as evidenced by pre- and post analyses of attitudes and understanding. What emerged in eighteen of the forty theses examined was the mention of the experiences of special needs students within the classroom setting. All eighteen studies noted the positive impact of design technology experiences for engaging students with special needs and encouraging them to be more active participants in the classroom.

Teacher Change

Becoming a teacher-researcher has been a transforming experience for the MA/MST teachers. Their view of themselves has changed from being someone who delivers instruction to someone who acts as a facilitator of students' developing knowledge. The districts where the teachers are employed vary tremendously in socio-economic terms. There are urban districts with overcrowded classrooms with children from single parent families and little home support, as well as affluent suburban districts with predominantly intact families, and working class suburban districts that share many problems similar to those that the urban districts face. However, DT has transformed teachers in all settings. For instance, Michele reported:

> The results of this study and the children's enthusiasm are motivating me to apply this approach to all of my units of study. The children have learned such a great deal through the integration of mathematics, science, and technology into this unit on sound. I personally enjoyed the authentic assessment I was able to use with the children as a result of the activities in this unit. The process of observing them performing tasks gave me a better understanding of how to structure my classroom with more of a constructivist approach where the children are doing the inquiry.

Helping teachers to create "space" for students to actively seek solutions is a goal of the MST Masters Program. It is easier for some teachers and differs according to their current setting, background experience, and basic assumptions about teaching and learning. Challenging their assumptions and inviting them to critically analyze their philosophies is part of the program's pedagogical approach. Lisa G. noted:

> Taking into account the analysis of this total unit, the results have renewed my belief in and commitment to integrated MST teaching. Hands-on problem solving and decision making through design and construction have enabled my students to make many real life connections and become part of the world of math, science and technology that exists in the world outside of our classroom.

The awareness that children are able to have deeper understanding of material and make interconnections with the world around as well as other subject areas is demonstrated by Donna's observation:

> I have a new respect for my students after interacting with them as we implemented this unit…Prior to this unit I held a belief in the integration of curriculum, but now I have valid evidence that integrated curriculum is meaningful and promotes higher level thinking, conversation, and problem solving. Integrating all the subject areas is a worthwhile approach for all.

One teacher/graduate student implemented DT in the social studies curriculum in her district. In her fourth grade curriculum unit on Native Americans, she challenged the students to work in groups to design and construct models of Native American homes. The students had to connect the types of homes with the geographic regions where the tribes could be found and the ways in which the homes adapted to climates associated with these regions. This teacher (Cathy) remarked:

> Integrating the disciplines showed the class how pieces connect and fit together in real life. It shows how no one subject is isolated. Mathematics and

> science work together. Integrating the unit also allowed the theme to develop over time, and the students' interests were allowed to grow and expand. Isolating this unit into only social studies would not have given the students all the knowledge they have acquired. I feel turning a topic into a MST unit allows for ideas to flow and overlap which will provide the child with a deeper and more enduring understanding.

In addition to the insights the teacher-researchers were able to develop about how children learn, and how to authentically assess their levels of understanding, their input is sought in designing curriculum for the school districts. Lisa S. pointed out: "As a member of my district's science committee, it is my hope
that I will be able to encourage and assist my district in their desire to find the MST connections in our science curriculum. It is my hope that we will be able to eliminate some of the overlap that exists between grade levels and focus on 'quality rather than quantity.' By this I mean that I would like to see each grade focus on several integrated MST units per year rather than 12 segregated science topics."

Student Change

The graduate students/classroom teachers also reported how their students' learning was transformed. Students became active-learners, assuming responsibility for their own learning where the teacher was a guide, but no longer the sole resource. Michele observed that:

> From the integration of mathematics, science and technology into this unit on sound, I can conclude that every student became an active learner. The children demonstrated the ability to pose questions, seek answers, and test solutions. Each student turned into a 'problem-solving machine' as we underwent the challenge of constructing musical instruments. The scientific method of stating a problem, making a hypothesis, listing materials, planning a procedure for action, observing, recording observations and drawing conclusions was also exercised in this experience. The students were able to apply science ideas learned in this unit as well as previous units in order to build something.

The very goal of enhancing students' understanding of science concepts by asking them to design an artifact that applies those concepts is evidenced here. Further, Lisa S. reported that:

> It was evident that the children's perceptions of science had changed dramatically because of the enthusiastic way they approached doing the investigations, gathering data and the other aspects of the unit. As they took a more active role in decision-making and problem solving, they increased in confidence. Their discussion time really became a forum for the comparison of experiences and the sharing of new solutions and ideas. They no longer looked to me as the source of information or the solver of all of their problems.

> They now see themselves as 'knowers,' confident and capable of investigating possibilities and answers they needed to find.

The students' depth of understanding, making connections with the world around them is also enhanced by the DT unit. Danielle noted regarding a rainforest unit in which:

> Not only did the students gain knowledge about the importance of this sanctified habitat, but the students' confidence towards math increased, and their beliefs about science broadened. It is salient that the students have taken more responsibility for their learning as well. The students have become familiar with and have come to understand many concepts and ideas relating to the rain forest environment. They recognize how we are all part of an interconnected community where an individual's actions can have a direct or indirect impact on the environment.

In an integrated unit on the seashore, first graders were designing a three-dimensional model on a seashore mural. This involved measurement and early concepts relating to scale. Donna found that:

> By unleashing the students and giving them more control over what they were learning, more complex ideas were discussed. It was wonderful to see children integrating subject areas. Our science discussions led us to experiment, and to read literature and to do research. First graders were thinking about measurement, scale, and shape as they built their project. I saw students looking for rulers and cylinder-type materials to use for their projects. Students were making murals of the seashore at home before I even introduced the model seashore project. By the end of the unit students were attempting to write seashore poetry independently, which led to our lessons on poetry. In Writer's Workshop, students were writing books with a seashore theme before I even realized. They perpetuated the integration of subjects and benefited.

Critical thinking skills are so important to develop: the ability to analyze a situation, to apply the knowledge gained, and to gain new insights in the process of doing so. They pose questions and then seek solutions through their own investigations. Elizabeth noted:

> The students have improved in their research skills. This was evident by the contrast between their ability to look things up independently when I first arrived compared to this point in time. Many will now say they had a question, but found it in a book or on the Internet and discovered the answer for themselves. The students continued to research information on aviation after the "official" unit was over.

Jennifer corroborated this from observations of her class:

> Incorporating a design challenge is what made the unit come together. The students had all this information and nowhere to put it. It was during this

> part of the unit where everything clicked and the students began using the knowledge they acquired of the rain forest. The design brief and project, while relying on rubrics for assistance, then challenged the class. This was the first time students were given complete freedom to design a project with few constraints. The outcome is outstanding.

Special Needs Students

Many of the graduate students/teachers had classrooms where previously segregated students with special needs are mainstreamed into the life of the classroom. Another teacher joins the students, often contributing as a team teacher to the class instruction, while specifically supporting these students in learning activities. Consistently, teachers have reported that children with special needs, lower functioning students in the traditional academic setting, gain knowledge and self-worth while participating in DT units. They are able to equally participate in group design projects. Lisa G. noted that:

> The two students who were "lower functioning," who have experienced sporadic success by traditional methods, were able to participate fully and experience completion, sustained success, and share in the sense of accomplishment from a job well done

Lisa S. recorded a similar experience in her teaching journal.

> This unit also allowed lower-functioning students who had in the past experienced success rather sporadically, to now experience success on a daily basis. I feel that the reason for this is because the unit encompassed so many learning styles that each child was able to strive and succeed regularly. As a result, students felt better about themselves and were more willing to take risks not only during the work on this unit, but on work in other subject areas as well. Students who used to sit quietly and need to be called on were now active participants who shared willingly and weren't afraid to be wrong. They seemed to try harder and be more enthusiastic about what was happening in the classroom.

Ann Marie also noted that the unit on designing snail habitats could foster improved learning and understanding in her lower functioning students:

> The students' faces would light up when I mentioned the word "snail" because they realized that they were going to get to discuss how much they had learned followed by time to observe and explore the snails. . . . the low functioning students could share just as many snail facts as the others could. I was amazed that they could remember this information because if I asked them to spell their name they sometimes had trouble. These students can even give the definition of such words as hibernation and tentacles. They can not always pull the words out, but once the word is said they can define the term.

Tina found that integrating design minimizes the need for teacher intervention in DT unit on weather.

> I was happy and surprised to observe the significant amount of students who immediately wanted to participate when I asked for ideas to place on the first cloud. I noticed that one student's contribution would trigger a thought in another student's mind. Another thrilling experience for me was to witness my inclusion students participating in this activity, without teacher intervention. In the blended setting, the inclusion students tend to remain quiet because of the fear that the ideas they would like to share may be incorrect. The number of students in the class, along with their lack of skills, can cause extreme intimidation. As we completed this activity, however, they felt confident enough with the concepts they were familiar with, to offer many excellent ideas.

Conclusions

The graduates of the MA/MST program have improved their capacities for becoming reflective teacher/practitioners. The intensity of creating and implementing an elementary school unit centered on design technology in one semester is a challenge, one to which all have risen. Meeting with their peers who are experiencing the same process, conferencing with their mentors, and feeling the commonality of experience from frustration to jubilation, has furthered the realization of the transformations occurring in their classrooms. The transformation from teacher-centered to student-centered classrooms has caused them to reflect on how this has occurred. One point of consensus is the evidence that multi-disciplinary curriculum is meaningful and promotes higher-level thinking, conversation, and problem solving by children. Design is found to be inherently integrating; it is the keystone that brings the unit together. Teachers found that authentic assessment of student work caused them to further reflect on student learning and their role in that process. The process of observing students performing tasks provided an enhanced understanding of how to structure classrooms for a more constructivist approach to learning.

Equally important has been the willingness to shift to more student-centered learning and to monitor the students' enthusiasm towards learning. Their students became active learners and problem solvers. Indeed, their critical thinking skills, as evidenced by their ability to pose problems, seek answers, and test solutions, expanded and extended to other curriculum units. Their confidence increased, as they had to take responsibility for their own learning, becoming capable of researching, and finding answers to questions they posed for themselves. The questions became more complex and interrelated. No longer were curriculum areas isolated; mathematics, reading, writing and science are connected through design.

One of the most significant results from units centered on design is the benefit it has for inclusion students or students with special needs. All of the teachers who found that their inclusion students benefited from the experience, in ways they had not from traditional classroom learning activities, realized that the design process enfranchises a variety of learning styles, from the traditional academic instruction to the creative and eclectic.

In order to implement design technology, the teachers had to let go of their central roles in their classrooms and create a more student-centered environment. They were surprised at the way their students assumed responsibility for their own learning. Children, when empowered, more actively participate in class discussions and perform better in cooperative groups. This is accomplished as a result of their enthusiasm for the design process and the construction activity.

The process of writing about their experience, gathering the data, and analyzing the data deepens the teachers' capacities to think intellectually. By becoming thoughtful problem solvers, they enhance their own capacities for reflection. The professors continue to struggle with how to build upon the reported and observed strengths of integrating project based units into traditional elementary school curriculums. What continues to evolve is the powerful connection between graduate in-service teacher education and its potential for directly impacting daily classroom practice.

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Factors Affecting Students' Performance in Sixth Grade Modular Technology Education

Richard A. Weymer

Abstract

This study examined relationships between cognitive style, verbal ability, quantitative ability, prior knowledge, motivation, and achievement in modular technology education. Data were provided by 78 male and 64 female suburban sixth-grade students ($N = 142$). The Group Embedded Figures Test, Children's Academic Intrinsic Motivation Inventory, Comprehensive Testing Program III verbal and quantitative subtest scores, and a researcher-developed achievement test were used to collect data. The treatment consisted of three computerized activities. Statistically significant relationships, at the .05 level, were demonstrated in the bivariate analysis between achievement and: (a) cognitive style, (b) verbal ability, (c) quantitative ability, (d) prior knowledge, and (e) motivation. Multiple regression analysis revealed a statistically-significant model for prior knowledge and verbal ability ($F = 46.52$, $df = 136$, $R^2 = 63.1\%$, $p < 0.05$). A low-achievement profile emerged with this sample.

Introduction

A debate is raging within the technology education profession relative to the acceptance of modular technology education (MTE) and the rejection of other approaches, such as the project-based method of instruction (Weymer, 1999, p. 1). Gemmill (1993, p. 14) defined MTE as a "self-contained instructional system for self-directed, individualized instruction." MTE is generally thought of as a curriculum provided by a commercial vendor in which students learn about an area of technology by: (a) participating in interactive media presentations, (b) following instructions in workbooks, (c) writing responses in student journals, and (d) experimenting and building projects. Working in pairs, students complete instructional activities at computerized work stations. Students follow self-directed instructions that introduce and reinforce technological concepts. Many MTE curricula have a strong "hands-on" component in which students use tools to process resources, generally resulting in a completed prototype or experiment.

Personal computers are replacing the classroom teacher as the disseminator of technological content and processes in modular programs. The modular

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approach is relatively new to our profession and largely untested as to its instructional efficacy. Furthermore, MTE is replacing traditional technology education programs at an unprecedented rate.

In an effort to determine the prevalence of MTE programs in America's public schools, the following strategies were pursued: (a) the main MTE companies, in terms of market share, were contacted relative to numbers of installed labs, (b) data were compiled relative to secondary school counts, and (c) percentage frequencies were calculated for middle and high school MTE facilities. Representatives from eight companies were contacted. For purposes of this study, an MTE lab consists of eight or more modular work stations with a computerized management system. Six of the eight companies contacted were willing to reveal the number of MTE labs that they have installed as of September 2001. Among the six responding companies, there were 5,088 middle-level and 2,177 high school MTE labs.

The researcher has determined the existence of 17,542 public middle/ intermediate schools in America and 15,391 high schools (Moody, W., Ostdick, R., Rascher, C., & Thiessen, J. 2000, p. vii). Middle/intermediate school numbers were compiled by adding secondary school counts by states in *Patterson's American Education* 2000 edition data for grades 5-9, 7-12, and K-12. Data for high schools were compiled by adding data for grades 7-12, 9-12, 10-12, and K-12. Dividing 5,088 by 17,542 indicates that 29% of American middle/intermediate school contain a modular program. Similarly, dividing 2,177 by 15,391 indicates that 14% of American high schools have modular programs. These MTE frequency data are conservative estimates since only about three-quarters of the major MTE companies provided data and because both 7-12 and K-12 schools were used in calculating both middle/intermediate frequency and high school frequency numbers. These data support the widespread adoption of MTE across the US.

Through observation and teaching experience in a modular lab, the researcher has observed variance in students' ability to master the learning tasks presented via the computer-assisted instruction (CAI) used in MTE. Some students excel in modular programs while others struggle. What characteristics do students possess that enable them to become proficient at mastering the learning experiences presented in MTE? Conversely, how can technology education teachers, administrators, and MTE program developers address the needs of students at risk of failing to grasp the content presented in this learning environment? For example, 15% of the subjects in this study achieved less than 60% on the 50 point posttest used as the dependent variable.

As the modular approach replaces traditional technology education programs, questions arise concerning how students' individual traits and characteristics interact with the learning tasks presented in this instructional paradigm. Limited research has been conducted regarding these relationships.

Purpose of the Study

The purpose of this exploratory study was to investigate the relationships between achievement in one sixth-grade MTE program and students' individual traits and characteristics. More specific, this research examined relationships between students' (a) prior knowledge of the MTE content, (b) verbal ability, (c) quantitative ability, (d) intrinsic motivation, and (e) cognitive style with regard to performance on a posttest instrument. It was hypothesized that performance in MTE would correlate positively with students' prior knowledge, cognitive style, fifth grade verbal and quantitative ability scores, and intrinsic motivation. Further, this study sought to identify characteristics of low-achieving students in MTE, and to develop a regression model for predicting student achievement in MTE programs.

Review of the Literature

Jonassen and Grabowski (1993) have proposed a model divulging how the broad range of students' individual differences can affect learning. According to these researchers, a geographical metaphor can be used to describe individual differences. In this metaphor, the mind is compared to a landscape consisting of peaks and valleys. Just as topography within a region is highly variable and unique, so is an individual's mental landscape. The peaks in Jonassen and Grabowski's metaphor represent trait strengths, whereas the valleys represent the absence of specific learning abilities. “The relief on an individual's landscape treats abilities and personality variables as unipolar values. The particular combination of aptitudes and traits possessed by each individual is reflected in the individual's cognitive styles, personality, and learning styles” (Jonassen and Grabowski, 1993, p. xi). The study of individual differences is analogous to mapping the relief on individuals' mental landscapes.

Due to the analytic nature of most computer programs, Gupta (1996) hypothesized that students with a field independent (i.e., articulated) cognitive style would learn more effectively in a hypermedia computer environment than students with a field dependent (i.e, global) cognitive style. Gupta found significant differences in achievement between field dependent and field independent subjects ($F = 4.48$, $df = 50$, $p < .05$). Post (1987) found significant differences in achievement between field dependent and field independent electrical engineering technology students in logic circuit content presented with CAI lessons. Post reported that field independent students scored significantly higher compared with field dependent students ($M = 25.6$, $SD = 2.5$ versus $M = 22.3$, $SD = 3.9$, $t = 3.68$ $p < .001$). Post reported that 29% of the total variance on a CAI posttest was accounted for by the variables field dependent/independent cognitive style, sex, IQ, and age.

Prior Knowledge

Jonassen and Grabowski (1993) indicated that one of the strongest and most consistent individual difference predictors, relative to achievement, is prior knowledge. This study was concerned with the relationship between students' prior knowledge relative to a domain of knowledge presented in an MTE computer program and student achievement.

Research conducted by Guthrie, Van Meter, Hancock, Solomon, Anderson, & McCann (1998) showed a moderate correlation between prior and new conceptual knowledge in a study examining reading engagement processes ($r = .303$, $p < .05$).

Achievement Motivation

Intrinsic motivation, according to Naccarato (1988), Wigfield and Guthrie (1997), and Rezabek (1995), is the inherent drive or tendency to pursue tasks simply for the sake of pursuing them, without any outside influence or push or threat of punishment. Traditionally, schools emphasize the use of externally supplied rewards and punishments as a means of controlling behavior and in directing the learning process. Modular programs, however, require a shift away from external motivation strategies in which students are rewarded and punished by the teacher. MTE programs, with their self-paced CAI instructional approach, require students to be intrinsically motivated.

Rezabek (1995) found a significant correlation between intrinsic academic motivation and academic achievement ($r = 0.374$, $p < 0.0001$). Research by Wigfield and Guthrie (1997) revealed that children with higher intrinsic motivation read more ($r = .31$, $p < 0.01$) and with more breadth ($r = .36$ $p < 0.01$) than students with lower intrinsic motivation.

Cognitive Style

The descriptors field dependent/independent were used by Witkin, Oltman, Raskin, and Karp (1971) to describe the extent to which an individual's perception or attainment of information are affected by the surrounding contextual or perceptual field. Field dependents find it difficult to locate and extract information because it is hidden in competing stimuli. Field independents find it easier to extract the relevant information from the surrounding field. Witkin, Dyk, Faterson, and Karp (1962) describe a field independent as:

> The person who experiences in an articulated fashion has the ability to perceive items as discrete from their backgrounds, or to reorganize a field when the field is organized, and so perceive it as organized when the field has relatively little structure (p. 14).

Regarding field dependent people, Witkin, et al. (1962) stated, "the term 'global field approach' has been suggested to describe the style of functioning that involves submission to the dominant organization of the field and the tendency to experience items as 'fused' with their background" (p. 80).

Witkin et al., contended that, "individual performances are represented continuously along the analytical-global dimension of experiencing, rather than constituting distinct 'types'" (p. 80). "When we say that a person shows an analytical or global field approach, we mean only that he falls above or below the mean of his group on this dimension" (Witkin, et al., 1962, p. 80).

Meng and Patty (1991) have utilized this continuum of the analytical-global dimension proposed by Witkin et al. (1962) to group subjects into three cognitive style groups including field dependent (FD), field intermediate (FIM), and field independent (FI). According to this protocol, subjects scoring within one half standard deviation of the mean are considered to be field intermediate.

Due to the analytical nature of the learning tasks in MTE, field independents may learn more efficiently and score higher on the posttest developed for this study than field dependents. Research by Gupta (1996), Post (1987), Hansen (1980), Hansen (1983), Vaidya and Chansky (1980), Lipsky (1984), and Riding and Dyer (1983) has shown that students with a field independent cognitive style performed better than students with a field dependent style in mathematical and analytical tasks.

Academic Ability

In this study, academic ability was operationalized as subjects' verbal and quantitative ability scores from their fifth-grade Comprehensive Testing Program III (CTP III) test results. Verbal ability was defined as a student's "ability to apply knowledge of printed language structure and meaning appropriately, to utilize cognitive strategies in analyzing information and drawing inferences, to deduce relationships and generalize verbal attributes, and to predict outcomes and evaluate the appropriateness of predictions and strategies" (Educational Testing Service, 1995, p. 2). Verbal ability is analogous to reading comprehension.

Quantitative ability was defined as a measure of students' "ability to apply knowledge of mathematical concepts and principles, to demonstrate flexibility in thinking, to identify critical features in new situations, to make correct generalizations, and to compare mathematical expressions" (Educational Testing Service, 1995, p. 4).

Stothard & Hulme (1996) described reading as the interaction of two distinct processes, decoding and comprehension. For skilled readers decoding is a highly automated task. Skilled readers can focus their attention on comprehension of the novel material. Low ability readers typically have difficulties studying and learning from expository textual material (Helwig, Almond, Rozek-Tedesco, Tindal, & Heath, 1999). Readers with robust verbal ability skills are more likely to analyze new information and draw inferences than their peers with low verbal ability.

Variables

The dependent variable for this study was MTE posttest scores from a unit on engineering structures taught by CAI. Continuous (i.e., interval level) data were collected with a fifty point MTE posttest instrument developed by the researcher. The independent variables were: (a) academic ability with two levels of continuous data, including verbal and quantitative ability; (b) achievement motivation with one level of continuous data; (c) cognitive style with three levels of categorical data, including field dependent, field intermediate, and field independent, and one level of continuous data (i.e., raw scores), and (d) prior knowledge with one level of continuous data reported as students' pretest scores.

Research Questions

The objectives of the study are expressed in the following research questions:

1. Are there significant differences among the field independent, field intermediate, and field dependent cognitive style groups with regard to posttest achievement scores in MTE?
2. Are students' verbal and quantitative ability related to MTE posttest achievement scores?
3. Is there a significant relationship between students' prior knowledge, as measured by pretest scores, and achievement in MTE programs?
4. Is there a significant relationship between students' intrinsic motivation and posttest achievement scores in MTE programs?
5. Are students' cognitive style, verbal ability, quantitative ability, prior knowledge, and intrinsic motivation related to achievement in MTE programs?

Methods

Population and Sample

The target population for this study was all sixth grade students in a suburban school district in Lancaster, Pennsylvania during the 1998-1999 school year (N = 389). The accessible population for this study consisted of all students enrolled in the researcher's technology education classes during first semester of the 1998-1999 school year (n = 182). The sample consisted of students who returned their informed consent forms and that participated in the district's Comprehensive Testing Program III (CTP III) in the spring of 1998. The sample included 78 boys and 64 girls (n = 142). Students had an equal chance of being included in the study due to the district's practice of heterogeneous sectioning.

Procedure

Mandatory training sessions in the MTE learning environment were provided to subjects prior to the start of this study. A 50 point pretest was administered. This test was developed from the domain of knowledge included in a commercially available MTE program that focused on engineering structures. Subjects participated in three multimedia CAI activities over four class periods. The researcher monitored subjects' progress to ensure equivalent exposure to all material presented in the CAI lessons. The domain of knowledge included information about: (a) types of bridges and structures, (b) forces and loads, (c) impacts of structures, (d) construction cost and time, (e) various road conditions, (f) careers, and (g) a unit review. A 50 point posttest, identical to the pretest, was administered after the final multimedia presentation. The posttest was administered within four days of the final computer mediated presentation. Cognitive style of the subjects was determined through the Group Embedded Figures Test (GEFT). The motivation of the subjects was determined through the Children's Academic Intrinsic Motivation Instrument (CAIMI).

Description of CAI instruction. The CAI multimedia presentations used in this study consisted of narrated text, music, sound effects, video animations, photographs, and hypertext links. Activities started with directions presented on the computer monitor. Consistent with the instructional design of the module, dyads navigated the multimedia presentations at their own rate. The computer program used in this study presented several multimedia selections. Subjects were stopped by the CAI program to answer questions in an electronic journal. The CAI program summarized the material presented in each lesson.

Subjects needed critical thinking and problem solving skills to navigate the multimedia presentations used in this study. The researcher observed that many subjects were not following the CAI program in the proper instructional order and appeared to be confused. The researcher used a checklist to monitor progress and insure equal access to the CAI instruction.

Research design. A randomized one-group pretest-posttest design was used to determine the existence of relationships between the variables. The researcher used the following controls to limit the phenomena of test effect: (a) subjects received no feedback about pretest responses prior to receiving the treatment and taking the posttest, (b) two weeks passed between the pretest and posttest, and (c) subjects wrote their responses directly on the answer booklet in the pretest while they used optically-scanable sheets for the identical posttest.

Instrumentation

Pretest and posttest instrumentation. The researcher compiled and edited the 113 statements that represented the entire domain of knowledge presented in the engineering structures module. A panel of three subject matter experts reviewed the statements for face and content validity. A second panel of subject matter experts ranked the importance of the concepts presented in each of the 113 statements (i.e., 4 = very important through 1 = not important). Statements were grouped into categories according to the means of the rankings. Statements with a mean ranking of 3.0 or above were included in the pool of potential test items. The 15 items below this level were discarded.

From this domain of knowledge, two 50 item test instruments were constructed. These instruments (i.e., Form A and Form B) each contained 25 “best choice” multiple choice and 25 true and false items. The instruments were pilot tested in April and May 1998 with sixth grade students in the researcher's technology education facility. Statistical characteristics for these pilot instruments are shown in Table 1. Item analysis from the pilot tests produced 58 potential test items with high to medium r-biserial correlations. The pre/posttest instrument used in this study was developed by selecting 50 usable items from the two pilot tests. The statistical characteristics of the pre/posttest instrument are shown in Table 1.

Table 1
Descriptive Statistics for Pilot Test and Research Instrument

Instrument	*n*	*M*	*SD*	Range	KR 20
Pilot Tests					
Form A	87	38.02	5.17	23 – 47	.72
Form B	73	35.77	4.52	21 – 45	.61
Research Instrument					
Pretest	142	28.92	5.56	14 – 43	.70
Posttest	142	35.96	6.14	19 – 50	.80

Note. Form A and B administered as a posttest only, scale of measurement = 50.

Perception measurement. The GEFT is a perceptual instrument that measures cognitive style. It consists of two scored sections each containing nine complex figures. Each complex figure has simple figure embedded within it. The subject's score is the total number of embedded figures that were correctly traced in the two scored sections of the test. GEFT results in this study were used to place students along a field dependent/field independent continuum. The GEFT instrument yielded the following statistical results with this sample: M = 6.93, and SD = 4.54, Chronbach's alpha = .87.

Verbal and quantitative ability measurement. Subjects' fifth-grade CTP III verbal and quantitative ability subtests were used to determine academic ability. The CTP III test used in this study was normed for a suburban population (n = 3,000). The researcher did not have access to students' individual test booklets and, therefore, could not calculate sample-specific reliability for these CTP III subtests. Educational Testing Services (1995) reported the following K-R 20 reliability data for the instrument used with the norming sample: verbal ability r = .83, and quantitative ability r = .82.

Motivation measurement. The general motivation scale of the Children's Academic Intrinsic Motivation Instrument (CAIMI) was used to determine the intrinsic motivation of the subjects in this study (Gottfried, 1986). Chronbach's alpha was r = .82 for this sample. Construct and criterion-related validity have been established for the CAIMI instrument through the confirmation of hypotheses based on motivation theories (Gotfried, 1986, p. 13).

Data Analysis

Statistical procedures selected for the analysis of the relationships between MTE performance, academic ability, prior knowledge, motivation, and cognitive style included descriptive statistics of frequency distributions, means, and standard deviations. These data are presented in Table 2. Pearson's product moment correlations, *t*-tests, and linear regression analysis were used to examine the bivariate relationships between the response and predictor variables. These data are shown in Table 2. Multiple regression was used to examine the multivariate relationships between the predictor and response variables and to develop the regression model. An alpha level of .05 was used for all tests of significance.

Table 2
Variables, Scale of Measurement, Means, Standard Deviations, and Frequencies

Variable	Scale	*M*	*SD*	*n*
Pretest	50	28.92	5.56	142
Posttest	50	35.96	6.14	142
Verbal	100	50.15	28.95	142
Quantitative	100	52.13	27.48	142
GEFT	18	6.93	4.79	142
FD	18	2.10	1.21	42
FIM	18	6.98	1.35	52
FI	18	12.91	2.47	48
CAIMI	80	68.20	8.23	142

Results

This research attempted to explore how students' individual differences affect performance in MTE. The one-group pretest-posttest design, used to determine the existence of relationships between the variables, limits the generalizability of the findings. Research results should be interpreted conservatively.

Cognitive Style and MTE Achievement

Significant differences between the field independent, field intermediate, and field dependent cognitive style groups were revealed in the bivariate analysis with regard to MTE posttest scores. In this analysis, the GEFT cognitive style was coded categorically (i.e., FI, FIM, or FD). The FI cognitive style group was used as the baseline for comparison. Significant differences were revealed between the FI and FIM ($t = 3.35$, $p < 0.05$) and the FI and FD ($t = 6.10$, $p < 0.05$) groups.

Ability and MTE Achievement

Significant relationships were demonstrated in the bivariate analysis between students' verbal and quantitative ability and MTE posttest achievement scores. These results are shown in Table 3.

Prior Knowledge and MTE Achievement

A significant relationship was demonstrated between between students' prior knowledge and MTE posttest achievement scores in the bivariate analysis. This result is shown in Table 3.

Instrinsic Motivation and MTE Achievement

A significant relationship was demonstrated between students' intrinsic motivation and MTE posttest achievement scores in the bivariate analysis. This result is shown in Table 3.

Multivariate Analysis

Statistically significant relationships were revealed for verbal ability and prior knowledge, with regard to posttest scores, in the multivariate analysis. The variables of cognitive style (continuously coded GEFT scores), quantitative ability, and intrinsic motivation (CAIMI) displayed nonsignificant relationships in this analysis. The regression model, presented in Table 4, explained 63 percent of the total variance observed on students' posttest scores and was statistically significant ($F = 46.52$, $df = 136$, $p < 0.05$).

Table 3

Bivariate Correlations and Regression Results Between Predictor Variables and MTE Posttest Scores

Variable	Correlations	Bivariate	Regression	Results
	R	R^2	t	p
Continuous GEFT	.541	29.3	7.68	.000
Verbal	.731	53.4	12.68	.000
Quantitative	.632	40.0	9.65	.000
Prior Knowledge	.742	55.1	13.16	.000
Motivation	.255	6.5	3.14	.002

Note $n = 142$, 140 degrees of freedom in the regression analyses.

Table 4

Multiple Regression Results for the Independent Variables with MTE Posttest Scores as the Response Variable

Independent Variable	t	b	r	p	VIF
Prior Knowledge	4.65	.42	.742	.000	2.5
Verbal	2.99	.06	.731	.003	3.4
GEFT	2.04	.17	.541	.075	1.6
Quantitative	1.24	.02	.632	.218	2.5
CAIMI	-0.27	-0.01	.255	.787	1.2

Note $F = 46.52$, $df = 136$, $p < 0.000$, $R^2 = 63.1\%$, intercept = 18.5.

Conclusions

Statistically significant relationships were demonstrated in the bivariate analysis between the MTE posttest and: (a) cognitive style as measured with the GEFT instrument; (b) quantitative ability and verbal ability as measured with subjects' fifth-grade CTP III test scores; (c) prior knowledge as measured with the pretest; and (d) motivation as measured with the CAIMI intrinsic motivation instrument. The bivariate analysis also revealed statistically significant differences between the FIM and FI and the FD and FI cognitive style groups relative to MTE posttest performance.

The magnitude of the relationships between students' posttest scores with verbal ability and prior knowledge was surprising. As bivariate predictors, verbal ability accounted for 53.5% and prior knowledge 55.1% of the total MTE posttest variance in this sample.

Multiple regression was used in the multivariate analysis to determine the existence of relationships between MTE posttest scores (dependent variable) and the students' cognitive style, verbal ability, quantitative ability, and intrinsic motivation (independent variables). Based upon the bivariate analysis, it is reasonable to conclude that verbal ability and prior knowledge enable a student to do better on the MTE posttest. Quantitative ability, cognitive style, and intrinsic motivation correlated significantly with MTE posttest scores in the bivariate analysis. However, these variables "washed out" in the multivariate analysis. The predictor variables used in the multivariate analysis did not show multicollinearity with each other (i.e., variance inflationary factor 5). These data are reported in Table 4.

Several possible explanations were found in the data for the non-significant relationship between CAIMI intrinsic motivation and the MTE posttest. In the regression equation the beta value for CAIMI was -.01. Used as a predictor of MTE posttest scores, CAIMI actually took away from the overall strength of the regression model. CAIMI displayed a low correlation with MTE posttest scores in the bivariate analysis ($r = .255$). The CAIMI variable may not have been an accurate measurement of the intrinsic motivation construct. An alternative explanation is that the subjects in this study all displayed high levels of intrinsic motivation. For example, the CAIMI had a maximum possible score of 80 and the sample mean was 68.20, with a standard deviation of 8.23. The CAIMI scores were high with little variability.

The multiple regression model developed in this study was used to determine whether students were at risk in terms of MTE achievement. A profile for low achieving students was developed in this analysis; the identification and remediation of "MTE low-achievers" was one objective of this research project. This profile was defined as students having scores one standard deviation below the mean on the MTE pretest, CTP III verbal and quantitative ability tests, GEFT cognitive style instrument, and CAIMI intrinsic motivation instrument. Using this approach, about 15 percent of the students in this sample ($n = 21$) were identified as low achievers.

The regression equation for the low-achievement group is:

posttest score = intercept value (i.e., 18.5) + .42 x pretest score + .06 x verbal ability score + .17 x GEFT score + .02 quantitative ability score -.01 x CAIMI intrinsic motivation score. Substituting scores one standard deviation below the mean on each of the predictor variables in the multivariate analysis predicted a low achievement group score of 58.8% [18.5 + .42 x 23.36 + .06 x 21.20 + .17 x 2.14 + .02 x 24.65 +59.97 x -.01] with a mean of 29.9, representing 15% of the students.

Students with low verbal ability, lacking prior knowledge, and preferring the field dependent cognitive style were especially at risk in this study. The researcher observed that many students preferring a non-analytical cognitive style got lost in the CAI learning tasks used in this research. These students had difficulty separating important information from less important details. Field dependent and field intermediate students lacked the analytical skills needed to navigate the computer-based instruction program used in this study.

Discussion

At-risk students can be identified and corrective action taken by helping them gain access to the material presented in the MTE program. The results of this study point to students' verbal ability and prior knowledge as two primary predictors of MTE achievement. Access to standardized test results and robust pretesting should assist practitioners wishing to identify potential low-achievers.

The results of this study call into question the utility of testing students on their cognitive style preference and intrinsic motivation level. Although these variables demonstrated statistically-significant relationships with the response variable in the bivariate analysis, it is doubtful that collecting these data would provide an adequate return on investment. Nonanalytical and unmotivated students should be identified and monitored. These students seem to lack the ability, and/or the will, to navigate the multimedia lessons and directions provided in the MTE program.

Recommendations for practitioners include: (a) identification of students with low-verbal ability at the onset of instruction, (b) the use of a robust pretest to identify students lacking prior knowledge, and (c) direct observation at the learning stations to identify students that prefer a non-analytical cognitive style.

The following strategies should be considered after potential low-achievement students have been identified: (a) obtain constant feedback from field dependent and field intermediate learners in regard to their progress through the computer program; (b) develop an enabling vocabulary list; (c) pair low-verbal with high-verbal students; (d) determine whether low-verbal students have mastered the content through daily check ups; and (e) provide enrichment activities for students lacking in prior knowledge.

MTE product developers should field test their products with diverse populations to determine whether low-achieving profiles appear. Also, MTE programs should have appropriate readability levels and they should include field-tested, logical, step-by-step directions presented only through the computer. The regression model developed in this study should have utility for MTE product developers and vendors relative to the identification of low-achievement profiles. If significant profiles appear, corrective action should be taken before marketing of the MTE product.

Research is lacking regarding individual differences and the instructional methodologies utilized in MTE programs. This correlational research was a first step at identifying factors influencing achievement in MTE programs. Replication studies should seek to determine whether similar results between these variables can be expected with diverse populations. Additional research is needed relative to developing effective CAI/MTE instructional design. Finally, an investigation of issues affecting policy decisions with regard to adopting MTE as an instructional paradigm should be pursued.

In theory, students should learn at their own pace and through their sensory preference in MTE. This appeared to be the case with regard to the high-achieving students in this study. Analysis of the data also revealed a profile for low-achieving students in this sample. For these children, access to the domain of knowledge presented in the MTE program was limited. This finding is disturbing in light of the increasing popularity of these programs. This result begs the question: "Why is the technology education profession anxious to abandon its traditional instructional methodologies in favor of an emerging, yet largely untested, curriculum innovation?" Based upon these findings, vendors should analyze their MTE programs to ensure that members of the low-achieving student profile are not educationally disenfranchised.

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Integrating Science into Design Technology Projects: Using a Standard Model in the Design Process

Bernard Zubrowski

Technology education at the elementary and middle school levels has been undergoing major revisions in recent years. There are currently a variety of pedagogical approaches to introduce elementary and middle school students to the processes and content of technological know-how and knowledge. These approaches span a range from a completely open-ended design challenge to a tightly structured, lengthy curriculum program. Given that there is an on-going debate about the nature of technology education and that current practices may be seen as transitional in nature, there are shortcomings in these practices that need to be addressed. One problem shared with other domains, such as science and mathematics, is a lack of depth. There is a need to balance the making of models or products with critical thinking. In addition, it is recognized that basic science knowledge would enrich and result in a more effective design process, at least in some areas of engineering technology. Given the time constraints of elementary and middle school teachers, this possible enrichment tends to be neglected. Coming at this from the other direction are science curriculum programs and teachers who recognize the highly motivating aspects of design problems. They tend to emphasize the inquiry process over the design process. What could be a mutually reinforcing and rich undertaking, where inquiry and design are dealt with in-depth, currently tends to be a situation where both are slighted. I will propose a pedagogical model that attempts to address this issue by advocating a special type of integration. This will be illustrated by a case study of a 4th grade class building and investigating a model windmill. I will illustrate how the introduction of what I call a “standard model” can be used to help students develop some basic scientific understanding, which can then be applied to making a more effective design. I will also discuss some issues of implementation that need to be addressed if such an approach is adopted.

Characterizing Different Approaches to Design Engineering

Before elaborating on this pedagogical model, I would like to place it in a broader context of research, practices, and current thinking regarding the integration of science, math, and technology. Most of these practices and curricula can be characterized into four basic categories through the examples that follow.

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1. Students are given a challenge having defined constraints and a set of materials. The teacher provides some guidance but the students are pretty much left up to their own abilities to carry through to a completed project. Here, both the design process and any potential science are implicit and undeveloped. A number of extra-curriculum programs seem to operate in this manner.
2. Design projects are presented to students in their science class. Teams of students assemble models with slight variations in their designs. Some experiments are conducted using the models, but these are not necessarily related to the improvement of the performance of the models or the overall design. The model is the means for introducing basic science concepts such as force and motion. The *Science Technology for Children (STC)* 4th-grade curriculum unit, "Motion and Design" is an example of this approach.
3. An integrated program of technology, science, and mathematics is organized around a "big idea" such as energy transformation. Concurrently, students might investigate the energy food value of trail mixes in math, measure heat energy in science, and experiment with photovoltaic cells in technology. This is part of a unit in the curriculum program *Integrated Mathematics, Science, and Technology* (1999). Similar kinds of juxtapositions happen in the *Biological Sciences Curriculum Study* (BSCS) middle school program. If there is design, it tends to be secondary to the teaching of science and technology concepts.
4. The fourth type of pedagogical model is a deliberate and explicit combination of design and inquiry. The overall context is a design project. Students are challenged to design and build a working model of a technological artifact, such as a flying toy, windmill, water wheel, or balloon-propelled car, with a limited set of materials and initial performance criteria. After preliminary models are designed and tested, there is a shift to a standard model, which is used to carry out inquiry providing for a more controlled context for introducing basic science concepts.

   Experimenting is a way to gain information about ways of improving the performance of the model as well as collecting data and evidence to support possible hypotheses about the functioning of the model. The hypotheses are connected with basic science concepts. After some experimenting, there is a return to the preliminary design models that are either modified based on the newly gained knowledge or completely redeveloped and tested. "The Flying Toy—Challenge 3" (SAE, 1999) of the curriculum program *World in Motion II* is one example of this approach.

It is this fourth example that I will develop in some detail. Taking this approach recognizes that design and inquiry are separable but closely intertwined. Each process needs to be given adequate and explicit development if students are to gain a sense of both. This would be in the spirit of the recently published *ITEA Standards* (2000) where it is stated that, "Design is regarded by many as the core problem-solving process of technological development. It is as fundamental to technology as inquiry is to science and reading is to language arts" (p. 90). The National Research Council and the American Association for the Advancement of Science also recognize the importance of design in technology by specifying a separate set of standards for technological design. As illustrated in the above examples, there are varying interpretations of how these standards get implemented, particularly in the context of science curriculum and practices in the classroom. I will propose that the first three approaches described above do not go deep enough in terms of design or inquiry.

Relevant Research for Integrating Engineering and Science

A limited number of studies have been conducted on the effectiveness of integration of science and technology. Childress (1996) reviewed some of this research and found results were inconclusive. His own study had equivocal results but suggested that there is a possible impact when the teaching of science concepts is introduced into a design project. Students involved in the *Technology, Science, Mathematics (TSM) Integration Project* (1995) worked with model windmills. The wind collector was hooked up to a generator. The challenge was to improve the performance of the collector as measured by electrical output. The experimental group was given one and one-half class periods each of special instruction in science and math. During a second iteration, the experimental group also received instruction related to the pitch angle of the collector blades. This is compared with the control group, which did not receive this extra instruction.

Childress concluded that "there was evidence that the students did, in fact, apply what they learned in the correlated instruction" (1996, p. 23). Through interview questions, students indicated that the specific demonstration with a Tinker Toy-type model seemed to impact their thinking. What was interesting and significant was the recommendation for future studies. Childress commented: "It is conceivable that the results of the pitch angle experiment were not transferable to the types of solutions that the students were working on; similar studies should use the actual student-made solution as teaching aids and demonstration props."

Here he is referring to the practice of using the Tinker Toy model for the demonstration while the students used other materials for their own constructions. He is recommending that the science experimentation be done with the students' own models. From my experience, the amount of exposure to the science part may not have given students enough time to fully assimilate the significance of its implications for their project. Both of these practices are incorporated into the example I will develop below which also involved working with model windmills.

Other research that is related to the issue of integration has studied how students approach problems in the school context. These studies suggest that elementary-level students, and to some degree middle school-level students, have a natural tendency to take school projects and turn them into challenges. Given a flying toy, students will naturally work to make it go farther or faster, or a model windmill, to lift more and more weights.

Schauble, Klopfer, and Raghavan characterized features of students' engineering and science models of experimentation in their 1991 study. They describe an "engineering approach" as one where there is comparison of highly contrastive instances where students search for variables that they believe are causal. The "science approach" is characterized as one where there is establishment of each important variable and a systematic testing of these variables. Students were given tasks that promoted these two different approaches. Significantly, the group that started off with an engineering task and then moved on to a science problem generated more inferences about variables. The authors speculated that the engineering task provides an easier entry point and a more focused goal for the students. During their work with students, Shauble, Klopfer, and Raghavan repeatedly asked them questions, attempting to get them to reflect on their learning. "Unless they receive practice and support in developing appropriate models of scientific inquiry, children's experimentation is characterized by narrow search, overemphasis on variables presumed causal, and difficulties in interpreting simple patterns of data showing covariation or lack of co-variation between candidate causes and events"(p. 879). These comments suggest that there has to be a deliberate and explicit move on the part of the teacher to take time in a design challenge to help students sort out relevant variables and conduct controlled experiments. This will be partly illustrated in the windmill case study I will present later.

The need for making thinking explicit is also called for when helping students gain a deeper sense of the design process. Kimbell, Saxton, Miller, Liddament, Stables, and Green (1997) generated a list of operational strategies, which they present as essential for students to go beyond functional skills to higher order thinking. Some of these strategies include iterative thinking, optimizing values, managing tasks over time, and collaboration. They claim that helping students become explicitly aware of these strategies will promote transferability across a variety of tasks. These strategies are dealt with in a more detailed manner by Kimbell, Stables, and Green (1996) in their outline of key stages in children's development of design capabilities. They isolate "facets of performance," which they consider central to the development of these capabilities. These are investigating, planning, modeling and making, raising and tackling design issues, evaluating, extending knowledge and skills, and communicating. As these are elaborated on in the case studies the authors present and the specific characteristics describing these processes, there is a mix of inquiry and design. For example, some of their descriptions of what constitutes investigation and extending knowledge and skills could be applied as well to describing processes of inquiry. Modeling and making are more clearly related to a design process but, as will be illustrated in the case study of model windmills, scale models are a context for dealing with both technological as well as scientific issues.

A curriculum program and teachers can present problems to students with specific goals but students have ways of reacting to these problems that may counteract these goals. For instance, Millar, Gott, Lubben, and Duggan (1993) investigated how children aged 9–14 interpreted an investigation in a school context. They observed that the students used several kinds of approaches (frames) in response to a posed problem. These were characterized in the following manner:

- Engagement frame: using the materials without any apparent plan or purpose
- Modeling frame: focusing on the physical appearance of the materials working to achieve an effect but not making any comparisons among characteristics
- Engineering frame: attempting to achieve an optimum effect
- Scientific frame: making comparisons, carrying out tests, and making conclusions about trends

Students initially started out working within one of these frames, but "over 75% of the changes of frames that occurred were towards an engineering frame" (Millar et al., 1993, p. 22). The authors' interpretation of these results has important implications. Children interpret a given task in a form in which they believe they can succeed. In other words, if a given task appears too demanding, it is reformulated, almost intuitively, as one which is feasible and manageable for that individual or group" (pp. 223–224).

These findings, as well as the experience of master teachers, suggest that students have to be brought to an explicit understanding of the need to carry out tests in a systematic way. This includes isolating variables, setting up controlled experiments, and making valid inferences based on evidence. Likewise, students need to reflect on the processes by which they arrive at a final prototype in order to develop an understanding of the design process. Younger students, it appears, need to be given explicit directions about ways to conduct controlled experiments and need to talk about how they are moving through a design problem. The challenge for the teacher then does not appear to be getting students to work at solving an interesting problem; rather, it is getting them to see the need to take time to conduct formal experiments and reflect on how the overall system appears to work. My impressions are that science teachers will attempt to do this often, but will neglect to also make explicit the design process and related concepts such as troubleshooting and optimization. Technology education teachers are supposed to emphasize and make explicit the elements of the design process. Why not try to find a way of bringing all of this together within the context of one project?

Integration of any set of knowledge domains needs also to be considered in the larger context of the *Third International Mathematics and Science Study* (TIMSS) results and their interpretation. As the most recent results show, U.S. middle school students fell behind those of other comparative countries even though they did relatively well as fourth graders. Part of the TIMSS project also involved a close look at the pedagogical practices of some of the participating countries. It became apparent that there are real differences in how the same subject matter is treated by teachers and the type of coverage given to this subject matter. By now the familiar phrase *depth versus breadth* has been a familiar cry of some educational leaders. What this means is also being debated, but there does seem to be a consensus that fewer topics should be explored and dealt with in greater depth. Projects that attempt integration are prone to cover a lot of content and process in a short amount of time. Any attempt at integration needs to address this issue.

Integrating Science into the Design Process

Based on work with technology topics, such as the Flying Toy Challenge (SAE, 1999), it has been found that a three-phase approach can be used that allows for a meaningful integration of science-type activities during the course of a design project. (Some current curriculum development efforts, such as TERC [formerly the Technology Education Research Consortium], seem to be proceeding along similar lines.) The first phase is an open exploration during which students are free to try out their own ideas attempting to build something that is functional but usually not very efficient. The second phase involves the adoption of what can be called a *standard model*. This is used to carry out systematic testing of essential variables of the system. The third phase is a return to the design process, using the newly gained knowledge to rebuild and make a more effective design. The key element of this approach is the use of a standard model. It is an essential ingredient, because it provides a knowledge base that can result in a more effective final design.

The First Phase-Open Exploration

The first phase should be a relatively open-ended exploration during which students are given wide latitude in trying out their own designs. This phase is similar to what Kimbell et al. (1997) described in their key stages of investigating (pp. 56–57). It is not a completely open situation, because they are constrained by the limited set of materials and specific performance criteria. During this time their mode of operation can be characterized as highly intuitive and based on tacit knowledge (Dorfman, Shames, & Kihlstrom, 1996). There are limited analyses of the overall challenge and any problems that occur. This means that if one observes students' behavior, it would seem they are deliberative in their constructions. But when pressed to make explicit their thinking, they have difficulty expressing coherent thoughts. Some may argue that it is premature to do so. Many of the newer curriculum programs encourage this exploratory phase. It does provide a way of letting students take ownership of the project.

Generally, after several sessions of working on these preliminary constructions, students need help in solving problems that have appeared and in deciding what steps to take next. In some cases, teachers may let them continue on their own, providing helpful advice but refraining from encouraging students to be systematic experimentalists. There is a point where students will reach a plateau. They make modifications on their preliminary constructions without achieving significant improvements. Continuing on this course eventually leads to frustration or loss of motivation to continue. Timely, helpful hints or explicit suggestions by the teachers can move them forward and result in improvements. Yet, these may be adopted without any sense of why they work.

Analysis of what is happening is neglected partly because each team has different constructions. In one type of possible scenario, the teacher would have to spend time with each team carrying out an extended discussion where the students examine what they have done. This is time consuming and requires special skills. In another scenario, there is some attempt at a whole class discussion where teams share their results. Since the constructions may often look different and lack comparable characteristics, the discussion can't go beyond a few of the common features. Given these circumstances, it is a challenge for the teacher to promote a deeper analysis of the design problems and develop a deeper understanding of relevant physical concepts. It is at this point when the teacher can introduce a second phase.

The Second Phase: Introducing a Standard Model

Students are asked to put aside their preliminary constructions and consider working with a *standard model*: a model that has been designed by one team or is suggested by the teacher. In both cases, the idea is to choose one that incorporates most of the features of all the other models that have been developed up to this point. This is a modified approach of what Kimbell et al. (1997), describe in their Key Stages in Modeling and Making (pp. 64–65). Alternatively, it is a model that will allow all of the teams to carry out a set of systematic experiments with the purpose of establishing a clearer understanding of how they can evaluate the most likely solutions to the posed problem. The teacher helps students isolate the most essential variables that can be tested. Controlled experiments are carried out to determine how these variables are related to the performance of the system they are designing. These experiments are followed by clear recommendations for improving the design of certain characteristics of the model.

Introducing the concept of the standard model has to be done carefully by the teacher. It has to be presented in a way that does not negate all the work done previously by the students. The teacher has to persuade the students that the standard model will build on what they have done, and allow them to get a better sense of what is possible and what works. This model should not be one that works so well that it forecloses any future development by the students; it should function well enough that consistent results can be obtained when experiments are conducted.

There are several advantages to introducing the standard model:

- It is a way of consolidating significant discoveries that have been made by teams in the open-ended phases of the investigation.

- It allows the teacher to move the students to carry out tests in a more controlled systematic manner.
- Since all of the teams are experimenting with the same model, results can be compared. Assuming care has been taken in the carrying out the experiment, the results will be more conclusive. There will be a larger amount of data collected so that patterns and correlation from this data will be more evident.
- Since all of the teams are involved, interpretations and explanations can be shared. The discussions will be focused, compared with a situation where each team carries out systematic experiments with their own particular model.
- Teachers are able to get at deeper issues regarding the physical working of the model. In order for the teacher to move students to a point where they are developing their own explanations and seeing the need for formal scientific conceptualization, there has to be a shared and highly focused experience.

These points are related to what Schauble, Klopfer, and Raghavan (1991) recommend and consider critical for helping students make explicit their thinking and in developing an appropriate model of scientific inquiry.

The Third Phase: Improving the Preliminary Models

Having spent some time working in this systematic way, students can shift back to a more open design process. They can incorporate their recently gained findings and conceptualizations into their preliminary models or go about coming up with an entirely new design. In either case, they will be working with a broader and firmer knowledge base and a more explicit understanding of the problem and possible solutions.

Taking this approach helps build up a knowledge base for the students. Design involves more than manipulation of materials and creative problem solving. The better the understanding the students have of the device, system, or materials, the more likely they can assemble a model that will meet or go beyond the original specifications. This phase has the same intent as the Key Stages of Kimbell et al. (1997), where they consider Design Issues and Evaluation. They give greater attention to the ultimate consumer of the products being constructed where here there is attention to the students attempting to meet the criteria given in the original formulation of the challenge.

Some educators will find this approach to be too restrictive of the students. It will be seen as taking away from the opportunity for students to come up with their own constructions and designs. To some degree, this is true. It may also end up possibly narrowing the designs of the final models. If the classroom teacher is very skillful and competent in inquiry teaching, he or she may be able to get each team to carry out the systematic investigations phase within the team. Discussion might be arranged to happen within each team. This is a great challenge. It is my sense of the contemporary situation that many elementary teachers are still just getting acquainted with an inquiry mode of teaching, and only a small percentage have done any real work in technology education. This holds, as well, for middle school teachers. Using a standard model approach can be a way of transitioning inexperienced teachers to a point where a class of students is taking multiple approaches.

Phases of Investigating Model Windmills

The pedagogical model of three phases using a standard model can be illustrated by following the development of a design project with model windmills. This is taken from one of the topics in the curriculum program, *Models in Technology and Science* (Zubrowski, 2001). Originally designed to promote learning about physical science concepts related to energy transformation, work, and power, it can be readily extended into an integrated design technology science project. The examples I will give of student's work are taken from a series of videos entitled *Windmills: A Video Case Study of and Extended Investigation in Technology and Science*, published by Education Development Center, Inc., 1999.

Open Exploration Phase

In the first session, students are challenged to build a working model of a windmill with a limited set of materials: eight index cards, four bamboo skewers, a small yogurt cup, an 18-inch thin metal rod, a metal tube (as shown in Figure 1), and a small fan for a wind source. They also have access to masking tape, staplers, and scissors. After viewing and discussing pictures of traditional windmills and making a rough sketch of a preliminary design, they are given the materials.

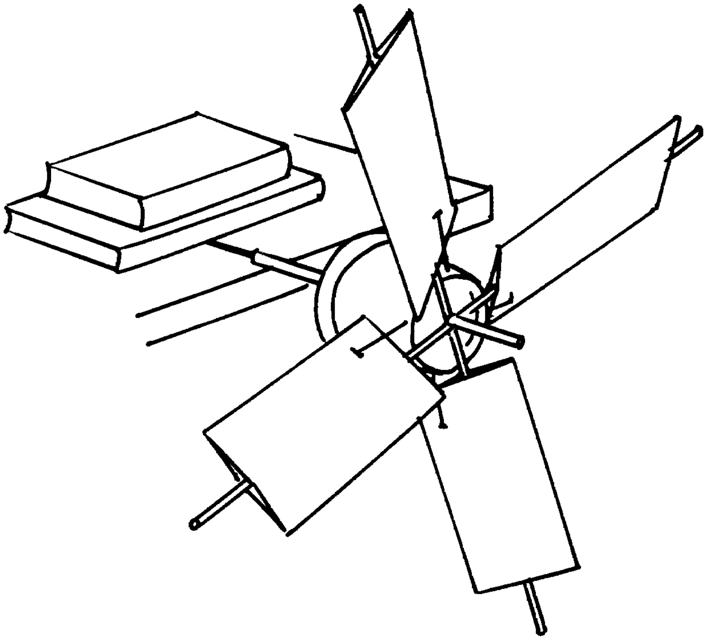

Figure 1. A standard arrangement of a working model of a windmill.

This problem has been presented to students with a variety of backgrounds and at different age levels. In most instances, they have been able to assemble a functioning model within one session. A second part of the challenge is to attach a string and cup to the rotating arms of the windmill so that it can lift weights. This will allow students to evaluate any changes they make in their models. The overall challenge is then to find ways of maximizing the lifting capacity of the model. It takes another session or two for students to find a way of attaching a string and cup to their models so that they can accomplish this.

Improvement of the design eventually centers on the number, orientation, and shape of the index cards attached to the bamboo skewers. In some ways, this may seem like a simple problem, but for elementary and middle school students, this project can go on for several weeks. From classroom observations of this project, the models they build during the first and second sessions barely function. Initially, students seem to be content with just getting something assembled that turns when the fan is pointed at the model. Their attention is totally given over to the construction rather than understanding how it might be functioning. Lots of sub-problems need to be solved within the overall problem of making the model function well. Students need to think about where to place the sticks on the cup that is acting as a hub, where and how to attach the cards to form the arms of the windmill, where to place the metal rod to allow the hub to rotate easily, where to place an axle, and how and where to hold the fan. Just solving these sets of sub-problems is challenging the full capacity of the students.

There are several important issues regarding this phase that are currently viewed from different stances. They are relevant to promoting an effective design process and in bringing out effective integration of science and technology.

- How many kinds and what amount of material should be given to students at the beginning of their exploration?
- How essential is this initial phase? Can it be eliminated or shortened so that the "real work" of creating a prototype is given the major amount of attention?
- How explicit and thorough a design plan can we expect from students before they even have explored with the materials?

The kind and amount of physical materials available to the students determines to a large degree what kind of project they can construct. In the case of the windmill model, they could be given a variety of small containers along with the yogurt cup, other kinds of paper and plastic sheets in addition to the index cards, and different kinds of rigid tubing. These added materials might have opened up the challenge, but they would also have increased the complexity. It is my experience in working with most students that providing them with lots of materials can overwhelm them. There is a tendency, particularly with elementary school students, to use up all the materials available to them. An underlying assumption for the students seems to be that if the materials were made available, then they were meant to be used. Students end up spending more time incorporating the materials instead of working on making their model functional.

What is relevant to this situation is the pedagogical principle of *manageable complexity*. The curriculum and the classroom teacher have to tune the challenge to the abilities, developmental level, and past experience, of the students. The more experience students have had with previous design projects, the more one can open up the challenge. If students are inexperienced, they need more structure. This can be arranged by limiting the type and amount of materials they will work with.

There is a need for a similar approach regarding the use of design briefs. To expect students to fully articulate how they would design and construct something before being given the materials is unrealistic. Unless they have done a great deal of construction activities at home or in previous school activities, they cannot anticipate all the problems that will arise. They need to play with the materials first, trying out different ways of joining them together. Particularly at the elementary and middle school levels, students have a real need to handle the materials to help them in their thinking. They need to put together the materials in a variety of ways, even if most of the resulting constructions aren't functional. They can see for themselves that certain arrangements just don't work. These comments run counter to some common presentations of the design experience. Charts in textbooks about design show that students should be putting together a design brief at the very beginning (Garrett, 1991; Hutchinson & Karsnitz, 1994). This is an idealized version of what can possibly happen with students at the elementary and middle school levels. Students have limited resources to anticipate and develop a full, realistic plan and solution unless they have had extensive experience with this process and know a lot about the particular device they are about to make.

This is not intended to preempt any pre-planning or preliminary discussions. The teacher can have students make some preliminary sketches, and have them discuss among the members of their team how they are going to proceed. There can be some preliminary research. In the case of model windmills, students can collect pictures of traditional and modern windmills. These can be used to help them form a plan of how they are going to assemble the materials given to them. However, there is still a need to recognize that some students "think with their hands." In the dialogue with the materials solutions start to arise. These kinesthetic learners are often the ones who are the most inventive (West, 1997).

This beginning exploration is a critical one that often is undervalued and considered just an introductory phase before the real design or scientific learning happens. To some educators this phase is mere play. It gets students involved and acts as a motivator, but real learning does not appear to be happening. This issue is addressed in a series of videos called, "Learning to See." These videos show elementary-age students exploring several different kinds of phenomena. When these videos are studied closely, the behavior of students reveals that play and exploration is purposeful. The manipulations of the materials and the students' ongoing comments indicate they are very much engaged and thinking about what is happening, much of which is at a non-verbal level. Students begin to make their initial conceptions explicit only after this more open and informal experimentation (Karmiloff-Smith, 1992).

In the video series *Model Windmills* (Zubrowski, 1999), 4th grade students spent five to six sessions creating somewhat consistently functioning windmills. The index cards used as arms started out in a variety of positions and shapes on the bamboo skewers, which were pushed into the yogurt cup. Eventually, the cards were placed in a more symmetrical manner. In the first few sessions, students taped the cards to the skewers without anchoring the end of the cards to the yogurt cup. The moving air from the fan caused the cards to flap around, resulting in an inefficient transfer of energy. By the sixth session, the cards were securely anchored with pins to the yogurt cup (this refinement introduced by way of the teacher) and could be fixed at an angle so that flow of air hit all of them in the same manner. This resulted in more weight being lifted by the models. During this time, students intuitively made changes that were needed, but were not able to articulate verbally why they were making these changes. For instance, they knew in some way that adding many arms to the windmill was counter productive, but it wasn't until the ninth and tenth sessions that they were able to articulate why this won't work well.

The behavior in this first phase is mainly intuitive. There is a fair amount of trial and error. The main pre-occupation is to put something together that works. Therefore, discussions in this phase are mostly descriptive. There is a sharing of what works and what doesn't. However, embedded in these intuitive acts and vague descriptions are latent theories and the foundations for moving to next steps. It is short sighted and counter productive to force students to stop at this point or to assemble a final prototype.

Part of the role of the teacher during this time is to help students get their models in some kind of effective working order. The goal during the later part of this phase is to concurrently improve the working of their models while also reflecting on the manipulations and the resulting change in results. Many kinds of questions can be asked at this point. The well-prepared teacher already has a sense of how the model is functioning, what some typical problems are that students encounter, and what kind of conceptions they bring to their understanding of how the device works. Using this essential background, well-formulated questions during this phase can be a subtle way of directing their attention and pointing out the importance of the observations and discoveries they are making. There are times, also, when occurrences can be exploited to move students to think conceptually about what they have just seen occurring. For instance, sometimes students will have a puzzled look on their faces. At moments like this, students can be highly motivated to puzzle over and attempt to come up with explanations. In the early phases their comments and explanations may not be well formulated, but they shouldn't be dismissed because they can be returned to later in the investigation.

Standard Model Phase

Exploration with the materials will reach a point where students have arrived at a consistently functioning windmill, but they aren't sure how to go about making further refinements. In the video "Windmills," one team of students was lifting 120 nails while other teams barely lifted 40. The other teams did not realize that the angle at which the arm is oriented on the cup can make a difference in the lifting capacity of their models. Often, another intuitive act is to place the fan on the side of the model instead of in front. This placement can make a real difference in the performance of the model. Students need help in seeing the significance of these discoveries, and they need to expand on these discoveries in a systematic manner. This calls for setting up controlled experiments. Shifting to this kind of context provides for the teacher an excellent opportunity to have students make explicit and discuss science concepts that are embedded in these more formal experiments. This is the kind of sense making that Schauble, Klopfer, and Raghavan (1991) propose as a necessary practice if students are to gain a greater awareness of scientific method as well as concepts. These discussions can help in their understanding of how a windmill functions which builds a larger knowledge base. This, in turn, gives them a better sense of ways to improve their original design.

When the teacher observes that students are not moving forward or are mainly operating in a trial-and-error mode, there are two approaches that can be taken:

1. The teacher can consult with each team and help the members plan out a series of experiments with their own preliminary model. The teacher can help them sort out the most salient variables and work out the experimental method by which they are going to be examined. If students have had extensive experience with design challenges and the inquiry process in previous years, this approach may be workable. However, if students are fairly new to independent work of this nature, it may result in inadequate and incomplete experimentation.
2. The teacher can have all the teams work with an agreed upon model that incorporates the salient characteristics of most of the preliminary models that have been constructed up to this point. The teacher needs to assure students that they will return to their preliminary models to continue to work on them after this beneficial, transitional phase. This step is not meant to negate their designs, but rather to help them think about what features contribute most to an effective windmill. This means maximizing the lifting capacity of the model.

Recall the study conducted by Childress (1996) previously mentioned. He speculated that students may have had difficulty transferring results from an experiment with one kind of model windmill to those they were constructing of their own design. What I am recommending here is that the experiments be conducted on a model using the same materials and of a similar construction as those already being used by students. Here, results are directly applicable to the students' own designs.

Once a standard windmill model is decided upon, there are several characteristics that can be investigated. Most of these involve the number and shape of the arms. Students can evaluate how the lifting capacity of their model changes as they go from 2, 4, 6, 8, and 10 index cards functioning as the arms of the windmill. They can also determine the best angle at which the cards should be set to align with the direction of the airflow and achieve the best lifting capacity. They can test to see whether placing the fan in front of the windmill gives better results compared with having it at the side. In each of these experiments, the teams share their results. If some care is taken, they will find that 45 degrees is the best angle for the orientation of the arm of the windmill, and that 8 arms is the optimum number to use. They will also find that the optimum placement for the fan is directly in front of the windmill rather than at the side. Establishing these conditions results in a significant difference in the lifting capacity of the model windmill. Initially, students have models that lift 30 to 40 nails. When changes are made in the above-mentioned characteristics, the model can now lift 140 nails. Students are very impressed by this difference.

By having all the teams carry this process out in a systematic fashion, they have the opportunity to share their results. Because similar results are obtained among the teams, there is greater confidence in the discoveries. More important, there is the opportunity to discuss why these changes made a difference in the lifting capacity of the windmill, opening up a discussion of science concepts. The teacher can challenge students to think about and discuss how the energy of the moving air is transferred to the arms of the windmill. With older students, some of the physics principles of work and power can be introduced. This becomes relevant when considering the kind of function a windmill will perform. The goal of these discussions is to have students reflect upon and analyze their results and connect them to basic scientific concepts. In this sense, the design process and science become intimately intertwined.

There is another added value for taking this approach. The systematic experimentation and careful consideration of the results provides a model of a *process* for the students. It shows them how they can carry out the same process with other kinds of design projects. When they return to their own preliminary models, they can utilize this process when making further changes. From a pedagogical point of view, the example with the model windmills illustrates that process can't be separated from content. If students experience this same kind of experimentation with a standard model in a number of specific contexts, they are more likely to gain a sense of a generic design process. Some writers have argued that students are more likely to develop these higher level cognitive skills by working through specific contexts than if these general skills were taught in some kind of direct didactic manner (Keil, 1991, p. 231). Using a standard model is one way to promote this kind of learning.

Culminating Activities or Explicit Consolidation of Findings

Having established some essential features of an efficiently functioning windmill, students can return to their preliminary models. At this point, they can be asked to be more detailed and thoughtful in revising their design briefs. They can make changes to reflect what they have learned from the standard model. In the situation with model windmills, further refinements can be made that might improve performance. For instance, they can experiment with different-sized arms. Up to this point, they have been using 4" x 5" index cards. Will there be a difference in lifting capacity if students use the same total surface area but they use a greater number of smaller arms (e.g., students can compare a windmill using four 4" x 5" cards with one using eight 2" x 5" pieces of cards)? Will it make a difference if the cards are twisted into a propeller shape? Will it make a difference if the length of each arm is made longer? These and other refinements can be considered. Each of these can be evaluated by carrying out systematic experiments. At this point, the teacher can also introduce new materials and a larger, more powerful fan. The challenge can be revised to reflect the addition of these materials. The overall design process can culminate in a final prototype after all of the different options have been considered. A formal presentation of their prototypes can also be included in this process.

During this last phase, there is also an opportunity to carry out some kind of embedded assessment. For instance, in one situation, the teacher presented her class with three, special model windmills after ten sessions. In appearance, they looked similar to the ones that the students had been using. However, they had been changed so that they did not function efficiently. The students were asked to determine by inspection and operation of these models what was wrong with them. One of the models had a relatively simple change. The rubber band holding the cup to the metal tube was removed. Although the body of the windmills was turning, it was not lifting the cup of nails The use of the rubber band was not apparent to the students in the first two to three sessions. In fact, it wasn't ever explicitly talked about in any of the sessions. However, most students noticed very quickly that it wasn't there. One of the three test models had a change had a change so subtle that it would not have been noticed if the students had not done extensive work with the windmills. The blades on the windmill were at a 45-degree angle to the skewer as they had been with several of the experiments the students had done. However, the orientation was reversed. This kind of arrangement of the blades does not work. The fan blades and grill cause air to rotate slightly in a counterclockwise movement, as shown in Figure 2. Some students noticed this difference and knew it was the reason why the windmill was not working efficiently.

Most of the students noticed what was wrong with each of these models. If they had been given these same models after the third or fourth sessions, they would not have had the experience to recognize the teacher's changes, especially regarding the windmill with the reversed blade orientation. The combination of observing what students do after discussions in changing their models, and presenting them with the challenge of analyzing poorly functioning models, are ways of assessing what students have gained from the activities.

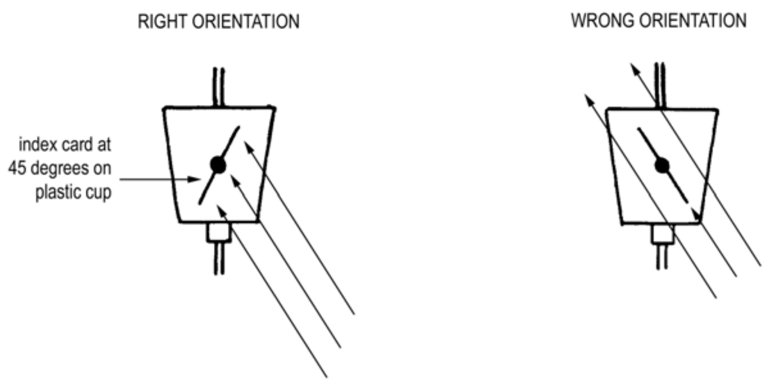

Figure 2. The right and wrong orientations of the arms of the windmill in relation to the air coming from the fan.

The overall process for windmill design using three phases and a standard model can be applied to other kinds of design projects: model water wheels, mechanical clocks, structure projects, different kinds of model vehicles, and related transportation models. These are all highly engaging projects and offer a rich context for both design and inquiry. As illustrated by the windmill investigation it is possible to direct students' attention to a deeper consideration of how a system functions in such a way that it increases their understanding of the system and at the same time enhances their understanding of scientific process and concepts. Working toward an effective final design provides the motivation to carry this out. Using the process outlined above helps the teacher to get at critical thinking skills that have been put forth by a variety of researchers and educators as essential if students are going to move beyond the mere act of making something and gain a sense of understanding at a metacognitve level of both the design and inquiry process. However, even if the form of this overall process is carried out it is still highly dependent on the sensitivity and skills of the teacher to help students make explicit their learning and truly benefit from this approach.

Issues and Realities

There are a number of issues that arise when attempting to bring about the kind of integration being presented here. Full integration requires close collaboration among teachers and dictates that students see the connection between subjects. In a survey of demonstration schools in Missouri, Nebraska, Colorado, and Oklahoma County School Districts, Wicklien and Schell (1995) found the following kinds of problems. The teacher team had difficulty working together. Some had problems committing to integrated projects. Students had problems seeing the connections between science, math, and technology, and in one situation, resisted a multidisciplinary approach. These findings suggest that integrated projects require a lot of planning on the part of the teaching team and that there is a need for a consistent pedagogical approach. When students experience an integrated project only occasionally in the midst of completely separated subject matter teaching, they have difficulty making the switch especially as they reach middle school. In a sense, the problem goes beyond teachers and students because it requires a restructuring of the school year and school culture.

Then there are two very important concerns regarding this three-phase process that will probably be expressed by some educators. One is that this approach requires weeks, not days, to complete. In the current push to cover all of the standards, do teachers have the time to carry this out? Another is whether this approach is really a design technology project, or is it a science topic using a technology context?

First, the approach being promoted herein needs to evolve over a period of several weeks. It takes this amount of time for most students to become thoroughly acquainted with the full challenge or problem, sort out the essential elements, and figure out how to test in a systematic way to obtain clear results. Building up this knowledge base, in addition to constructing an effective prototype, takes a fair amount of time. This kind of investment in time and effort will result in a more satisfying experience for the students, both in terms of affective and intellectual domains. The satisfaction is real, because they will have constructed a functioning model that gives measurable results. At the end of the investigation, they will also have seen progress both with techniques and understanding.

Despite calls at the national level for greater in-depth learning with fewer topics, this sensible recommendation is not being implemented at the local level. Teachers that I have worked with see the need for spending more time with a topic, and would like to develop topics in this manner. However, both the newer state frameworks and the current type of testing at the state level place teachers in a difficult position. They are accountable for making sure students do well on the tests. If the tests are designed to cover many different topics, teachers are forced to cover the same, however well this can be done in the time allotted for each topic. Until there is a paring down of standards at the state and school district levels, and a revision of assessment techniques to reflect this changed emphasis, classroom teachers will be unable to give students a richer and deeper learning experience.

Second, most science and technology educators would consider working with a standard model as I have outlined the process. The topic of windmills - as well as topics such as water wheels, vehicles, and clocks - is certainly part of the technological world. What is mainly at issue is the relationship between a design activity and the development of scientific understanding. I am proposing that design projects at the elementary and middle school levels will be much enriched and put on a firmer pedagogical foundation if there is an infusion of science process and content. Care has to be taken that the science doesn't take over the design process. On the other hand, science teaching will be greatly enhanced if it occurs in a design technology context. From my observations and teaching experience, students are highly motivated when working on a challenge or problem that is related to their personal lives or the world outside the classroom. This kind of context establishes a reason for developing explanations and attempting to understand how something works.

Finally, the example developed here is mostly related to one type of engineering and design project where it is difficult to bring into consideration the needs of a user or a relevant context. In the case of windmills, they can be related to the need for alternative energy production, which is currently receiving renewed attention. This makes it more relevant but still doesn't move students to incorporate user criteria into their design process. One way of dealing with this problem is to recast the challenge. For instance, in the Society of Automotive Engineers' *World in Motion II* (1999) curriculum, middle school students were challenged to design a toy vehicle for a fictional toy company and a set of plans for flying toys for a fictional publishing company. In the former, they were supposed to survey younger children in their school collecting information about the children's preference for toy vehicles. In the latter, results from a national survey on children's spending habits and toy preferences were provided. Students were to use these surveys in their assembly of a final prototype. This added another level of complexity to the overall design process but gave a greater relevance to it. However, it also meant additional time to fully utilize these results.

All of these issues suggest that science and technology teachers at the middle school level should move toward closer collaboration and develop ways of working on joint projects. There are big political and logistical obstacles to overcome, but it would seem to be worth the struggle. At the elementary level, teachers have more flexibility and may be more open to an integrated approach. Education and administrative support will be needed to help teachers consider such an approach and to develop the knowledge base to carry it out effectively.

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Special Feature

Research in Technology Education: Back to the Future

Philip A. Reed

The release of the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000) has spawned significant activity and literature addressing needed research in technology education. For example, the American Association for the Advancement of Science (AAAS) held a conference to look at what research would help to achieve the goal of technological literacy (Cajas, 2000). More recently, the National Research Council (2002) released a framework outlining three areas of standards-based research for mathematics, science and technology education. The three areas of curriculum, teacher development, and assessment and accountability reflect previous standards work in mathematics and science as well as the third phase of the Technology for All Americans (TFAA) project.

The research vision of these projects and the data provided by the ITEA/TFAA Gallup Poll (International Technology Education Association, 2002) give researchers clear lines of inquiry to further technology education's place within the context of general education. A new Council on Technology Teacher Education tool, the *Technology Education Graduate Research Database* (TEGRD), can also help with new lines of research. The TEGRD was specifically designed to highlight the history of research within technology education, provide a starting point for researchers, and to help scholars build upon past research as well as create diverse new research (Reed, 2001). Reflection on these three goals point out that previous technology education studies can help researchers prepare for the future.

With over 5,260 theses and dissertations in the TEGRD, spanning the years from 1892-2000, the history of graduate research in technology education is clearly highlighted. In illustrating this, however, Figure 1 shows that the total amount of research is not so important as its consistency over time. To demonstrate this point, consider the steady decline in graduate research after the name change from industrial arts to technology education (1985-2000). This is a disturbing trend during a period when inquiry to support the transition to technology education would have seemingly been substantial. Clearly this indicates that either there were fewer graduate programs requiring research and/or there were fewer graduate students pursuing advanced degrees.

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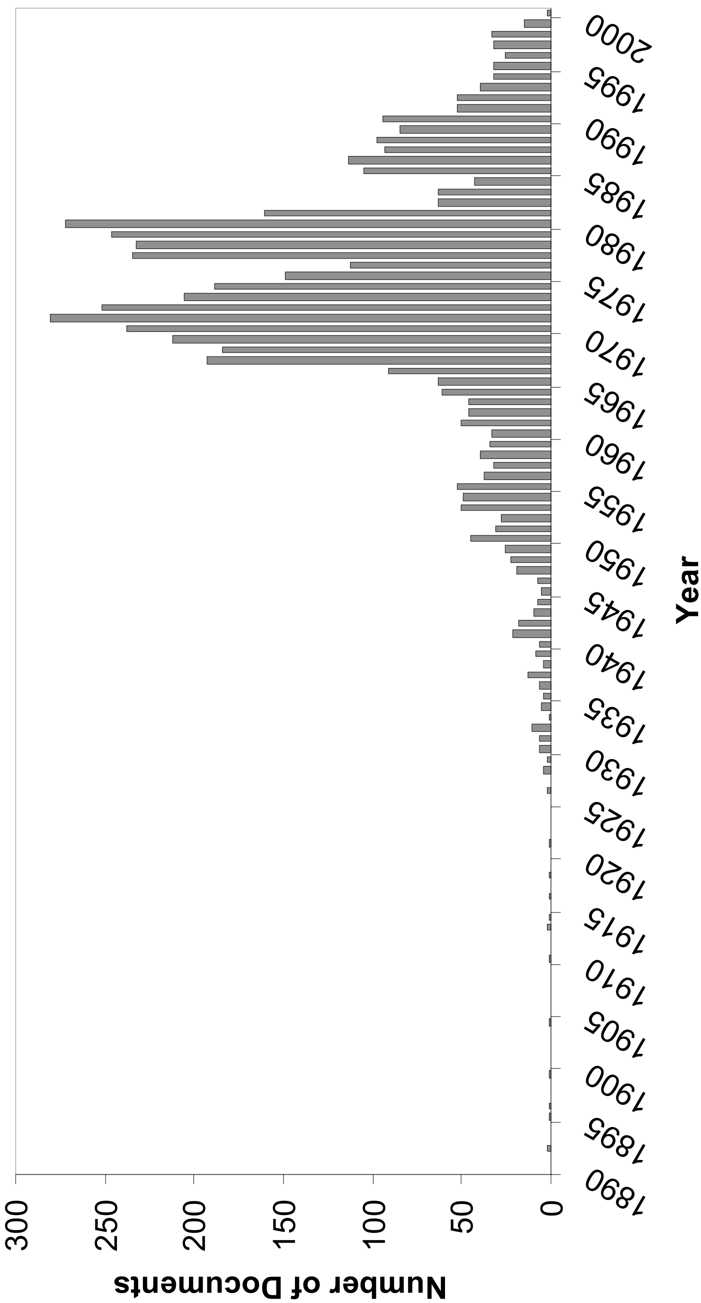

Figure 1. Technology education graduate studies by year (Reed, 2001).

For those graduate students who are conducting research, the TEGRD is an excellent starting point. Since entries in the TEGRD are based on the work of Jelden (1981), Foster (1992) and Reed (2001), they are more focused on technology education than other databases. For example, searching the terms "module" or "modular" in Dissertation Abstracts Online will yield many more returns dealing with nursing education and military instruction than returns pertinent to technology education. Searching the same terms in the TEGRD yields nineteen returns. This scenario is not meant in any way to downplay the importance of a broad-based literature review process. On the contrary, it is hoped that the TEGRD will be used as an additional tool to make literature reviews more robust. For instance, using the "module/modular" search example, a researcher should be able to make a more accurate connection to programmed instruction, self-training, and other behavioral systems that influenced the development of modular technology education.

A second look at Figure 1 shows the level of graduate research occurring between 1967 and 1981. Reviewing the history from this timeframe can help build upon past research and create diverse new research. For example, Cochran (1970) and Householder (1972) provided reviews of the vast number of curriculum development projects during the 1960's. Many of these projects were the result of federal funds provided by the 1958 National Defense Education Act, the 1963 Vocational Education Act, or private grants from organizations such as the Ford Foundation. Although these curriculum projects were developmental, several such as the Industrial Arts Curriculum Project were the catalyst for meaningful research. It is not difficult to draw parallels between this past pattern and the current state of technology education. The Technology for All Americans Project and the activities mentioned above have provided a significant foundation for researchers. Plus, federal funding is increasingly available to technology education researchers through the National Science Foundation (NSF) (Custer, Loepp, and Martin, 2000).

The call for a research base on technological literacy is also well documented (National Academy of Engineering and National Research Council, 2002). The TEGRD highlights the fact that there *is* a research base for technology education even though it is not solely focused on technological literacy. Naysayers may claim this is simply a disjointed compilation of studies. However, the key point is that technology education *does* have a historical foundation on which to build new studies. Figure 2 illustrates how to access the TEGRD both in print and as an online searchable database from the Council on Technology Teacher Education website (http://www.teched.vt.edu/CTTE). This tool will only be valuable if it is accessed and built upon. Looking back to the future, technology educators should be proud of the research they have conducted and the extent to which the profession continues to use it to forge ahead.

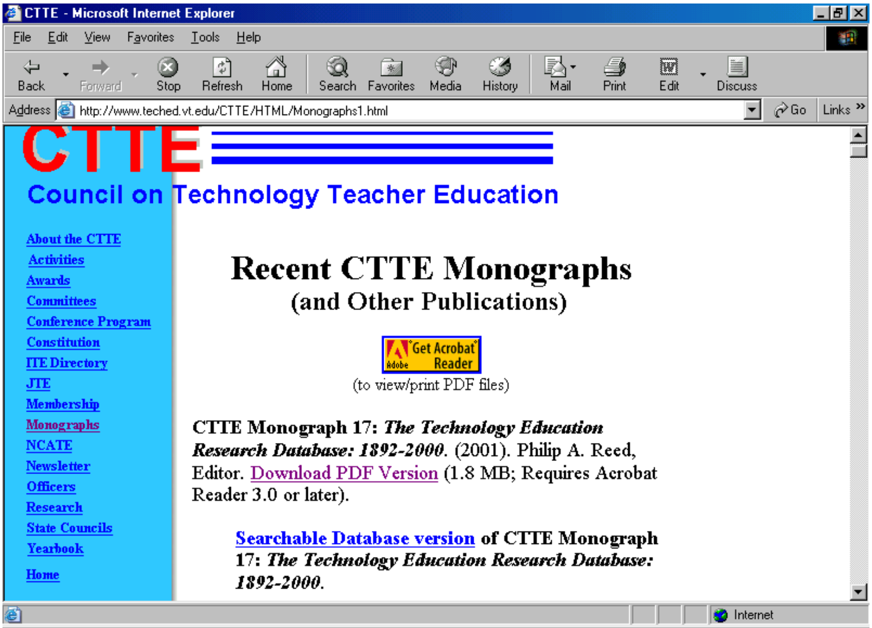

Figure 2. Accessing the TEGRD via the World Wide Web (Council on Technology Teacher Education, 2002).

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Book Review

Dorn, H. & McClellan III, J.E. (1999). ***Science and Technology in World History: An Introduction*****. The Johns Hopkins University Press, Baltimore, Maryland. $19.95 (paperback), $57.00 (hardcover), 416 pp. (ISBN 0-8018-5869-0).**

Reviewed by David M. Sianez

The relationship between science and technology has changed markedly during the last century. Science and technology, once clearly separated by philosophy and experience, have recently converged and now share similar boundaries and endeavors. To modern observers, the union of science and technology appears obvious and natural. However, the current interconnected nature of science and technology is vastly different from the historical evolution of each entity. Viewed through the lens of history, science and technology have until recently followed divergent paths throughout human invention and discovery. The union of science and technology has created an abundance of new knowledge that is often misunderstood. In the wake of this new information arises the need for increased understanding. The organization and dissemination of this knowledge will never be complete, but literature like *Standards for Technological Literacy* has attempted to organize these diverse topics. Quite often, knowledge and understanding of present conditions is accomplished by peering into the past.

James E. McClellan III and Harold Dorn present readers with an introduction to the history and relationship of science and technology in their text, *Science and Technology in World History*. The authors escort readers through a historical summary of science and technology, beginning with the emergence of tool use in human populations, progressing through world cultures and inventions, and concluding with trends in science and technology in the modern era. *Science and Technology in World History* consists of eighteen chapters separated into four parts. The latter include, From Ape to Alexander, Thinking and Doing Among the World's Peoples, Europe, and A Brave New World.

McClellan and Dorn begin to explore the historical relationship between science and technology in their introduction by criticizing current perceptions of science and technology. "Science has become so identified with practical benefits that the dependence of technology on science is commonly assumed to be a timeless relationship and a single enterprise…in most historical situations

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prior to the twentieth century science and technology have progressed in either partial or full isolation from each other-both intellectually and sociologically" (p. 2). McClellan and Dorn proceed to describe the use of technology throughout human history by craftspersons and laypersons. Craftspersons and laypersons have developed practical processes and inventions that shaped societies for thousands of years outside the scope of scientific study and inquiry. Only recently have the two entities merged to provide useful materials and processes by blending theoretical inquiry with practical knowledge and skills.

The authors conclude their text with an intriguing look into the past for insight into the future. Technology has served human needs and survived for approximately two million years. Creating modern instruments and tools still carries the same essential need humans faced when first fashioning primitive instruments, the desire to reshape the environment to suit their needs. The authors question whether the study of science, a relatively new endeavor, will continue to flourish or will fade away like ancient Greek and medieval Islamic science.

Why is this book worth your investment in time and money? Science and Technology in World History provides a broad view of the history behind science and technology that would enhance secondary technology education programs and collegiate technology education curricula. *Science and technology in world history* addresses technology benchmark topics specified in *Standards for technological literacy: Content for the study of technology (ITEA, 2000).* These topics include Standard 3 (relationships among technologies and the connections between technology and other fields), Standard 4 (the cultural, social, economic, and political effects of technology), Standard 6 (the role of society in the development and use of technology), and Standard 7 (the influence of technology on history). *Science and technology in world history* reveals developments within science and technology from diverse cultures and eras that are rarely discussed in typical science and technology literature. The book is relatively inexpensive at $19.95 (paperback), and is a viable supplementary text for cooperative learning programs such as science-technology-society, and technology education programs seeking resources to enhance technological literacy instruction.

Science and technology in world history was not created to provide an in-depth depiction of the relationship between science and technology, but rather an historical introduction to tempt the reader's appetite for further study. To facilitate additional studies, the authors include an extensive resource guide that includes book titles and URLs for websites that expand upon information discussed in each of the eighteen chapters. Whether for personal enrichment or classroom instruction, it is well worth consideration.

Reference

International Technology Education Association. (2000). *Standards for* *technological literacy: Content for the study of technology*. Reston, VA: Author

Miscellany

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

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