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From the Editor

Reflections, Fabbers, and Sharing Intellectual Property

About nine years ago I wrote my first From the Editor, titled *Nine years back and looking ahead* (LaPorte, 1998). At that time I summarized a bit of the nature of this *Journal* as it had developed over the first nine volumes. It seems appropriate to do that again in this issue as nine more years have gone by.

In reflection, a lot has happened over those nine years. We now have a set of curriculum standards for the first time and the profession has rallied around them in a variety of different, very positive ways. The interest in integrating technology, mathematics, and science has evolved into the current emphasis on engineering. A variety of organizations beyond our profession have become involved in technological literacy, both within the school and in the community. We can now access the Internet wirelessly in most hotels and airports, many coffee shops, nearly every college campus, and an increasing number of "hot spots" across the country. With a satellite Internet connection, people can take their "office" with them and do work virtually anywhere in the world and at any time, whether it is (tongue in cheek) under the Eiffel Tower or in the wilderness of the Montana mountains.

It seems that virtually everyone has a cell phone, including many elementary school children (and many parents depend on this form of communication). There is no respite from the mega-communication network that has evolved as long as we keep the switches turned on – and increasingly others expect us to do this. For good or for bad, the geographic location of any person with an active cell phone can be determined.

On the other hand, over those nine years we experienced 9/11, we became engaged in a war, and for the first time I worked with JTE authors whose lives were in danger as they developed manuscripts. Many advances in medical technology have occurred, but there is still no plan for those who cannot afford health insurance. We have started to come to grips with the reality of global warming and have begun to realize the grave consequences if we do nothing about it. Promising developments in alternative fuels to power our automobiles are occurring, though we glutted ourselves with low mileage vehicles, making everyone pay more for fuel because of the economic principle of supply and demand, including those conscientious about non-renewable resources,.

The economy has become even more global than it was nine years ago. Through the curriculum standards and other influences, our profession has become much more global as well. The fact that the international PATT (Pupils' Attitude Toward Technology) Conference is held every other year in conjunction with the ITEA Conference has made it a truly global event as well, spawning international collaboration in a variety of ways – we really have "grown into our name" and have become an international organization.

Nine years back I highlighted how "international" the JTE was, so I decided to compare the first nine volumes to the second nine volumes in this regard. As reported in Table 1, the number of articles authored by one or more international authors has increased dramatically, by more than 50%.

From the time I first started teaching I felt that the general education goals to which we aspired, and in which I still firmly believe, would be reached when there was an equal number of male and female teachers, and male and female students in our programs. Though the number of female teachers has increased more than 10 fold between 1979 and 1999 (Sanders, 2001, p. 41) females are still short of being equally represented in our profession. At the same time, though, the number of female students at the middle school level has nearly reached equality (Sanders, 2001, p. 43). I was curious to see the representation of females among the authors of JTE articles. As reported in Table 1, I found that this percentage increased 30% between the two time spans. Still, less than one in five published articles involved a female author, but the increase over time is quite encouraging.

In addition to authorship, I also took a look at the JTE subscriber base, counting those who had female first names. I did not count names that were gender neutral, so my count is an underestimate. I found 103 females (19.5%) among the 529 individual subscribers at the time the Fall 2006 issue was mailed. This is encouraging as well.

Table 1
Authorship of Articles in the Journal of Technology Education

	Volumes 1-9		**Volumes 10-18**		**Change**
	N	**%**	***N***	**%**	
Total number of articles	100		88		
Articles in which the author or one or more co-authors did not reside in the US.	27	27.0	37	42.0	+55.6%
Articles authored or co-authored by one or more female(s)	14	14.0	16	18.2	+30.0%

Through the leadership of then Editor Mark Sanders, the JTE went online in 1992. Soon, all issues were available electronically. The *Journal of Industrial Teacher Education* and then the *Journal of Technological Studies* followed suit soon thereafter, essentially opening up the scholarship of our profession to the world. I can remember the early days of accessing the JTE online when there was only one other publication so available. I can also remember soothsayers within our profession who believed that making the JTE available online would destroy the paper copy subscription base, and thus the revenue generated. This has not happened and paper copy subscribers are now around 600, an all-time high.

With full access to the JTE at no charge, it clearly can be considered part of the "open source" movement in this country. Wikipedia (wikipedia.org) is another example of an open source entity. Very popular with students, it is an online encyclopedia that is comprised of entries provided by anyone who wishes to contribute (yes, "technology education" is included). As the founders admit, there are inaccuracies, errors, and misinformation, but as time goes on, and because of the dynamic nature of the effort, corrections are made and the information becomes more valid. Though the term is often used in reference to computer programming code, Wikipedia includes a broad definition of "open source" as:

> … a set of principles and practices that promote access to the production and design process for various goods, products, resources and technical conclusions or advice.

In simple terms, open source could be considered as the paradigm for the open sharing of intellectual property. Most teachers are exemplars of this sort of sharing. In fact, most of the ideas that I use in my teaching are adaptations of ideas that someone else shared with me. Likewise, for those few ideas that were original to me, I feel tremendous satisfaction in seeing my former students, attendees at my conference presentations, readers of my writings, and friends, apply my ideas to their own teaching, improving the ideas in the process, and sharing those improvements with me and others. Though educators generally open-source themselves fully to others with their "intellectual property," the whole concept is often quite foreign to those in business and industry, where intellectual property is rightfully held very close to the chest and patent and trade secret protection and industrial espionage are a way of life. Educators operate under a sociological model whereas those in business and industry must typically operate under a competition-based economic model. As an aside, the differences between these two cultures must be reconciled before true cooperation can be productive.

One of the most significant technologies of interest to technology educators these days is rapid prototyping. Starting with a three-dimensional model developed with computer software, parts and products can be made as easily as printing a document from a computer. Rapid prototyping machines designed for educational use have become less and less expensive over time and will no doubt be in the labs of many secondary schools and colleges in the next few years.

Now let me connect open-sourcing with rapid prototyping. An exemplar of the potential of the doing this is Hod Lipson. He is director of Cornell

University's Computational Synthesis Lab. Hod clearly could have been a technology educator – as the article in *Popular Science* magazine stated, he "lost Lego pieces constantly" (p. 42). He has built a "prototype" of a rapid prototyping machine and calls it a "fabricator," or "fabber" for short. Between the article in *Popular Science* (2007) and his Website (fabathome.org), he provides all the details for replicating the "fabber." He is committed to the notion that collectively, his idea can be improved for the benefit of all. As he stated:

> We want as many people as possible to get their hands on this technology, experiment with it, and develop new applications for it. . . . We've put everything out in a completely free way, no limitations (p. 42; 44).

What a powerful concept! The article cites an example that has particular significance to technology educators. Noy Schaal, a high school student, won a first place in a "science" fair by using a "fabber" to produce a representation of *her* home state of Kentucky. The material used was chocolate!

Certainly intellectual property must be protected for reasons of national defense and to maintain the integrity of our vulnerable economic system. Likewise, creative efforts of individuals must be protected from those who might use them for their own personal or economic gain at the expense of the creator. At the same time, as I take increasing interest my own health and longevity (as most older people do), I would like to be able to read at no charge all the research articles (not just the "free ones") published in the *Journal of the American Medical Association*. Doing so could possibly extend my life and reduce the burden of my health care on society. Likewise, I feel that we, as a technology education profession, should have open access to the research and scholarship of those with similar purposes. Nearly every engineering and technology-related organization has some involvement in education, but with many of them you must be a member to access their educational materials. As an example, I refer to the American Society of Engineering Education (ASEE). The ASEE Website (www.asee.org) allows free access to all of the papers presented at their conferences over the past decade or so. This is a valuable resource, especially to those working to integrate engineering concepts into technology education. However, the scholarly journal of ASEE, parallel to the *Journal of Technology Education*, is the *Journal of Engineering Education* and is available online through their Website only to members.

We have welcomed the input of engineers into the development of our curriculum standards and we are sharing these standards with open-access online. The engineering community has given significant support to us in many ways as well. We allow engineers to freely access and publish in the *Journal of Technology Education* without being a member of the sponsoring organizations. I propose that we extend this collaboration and freely and openly share the scholarly resources of our allied organizations that pertain to education for our mutual benefit and that of the students we serve. I cannot come up with any negative tradeoffs to this proposal. There is no evidence that the JTE lost paper subscribers when all issues were put online – those in the field who are interested in research still want the paper copy, even though they do searching online. I am convinced that because of this open access we have exemplified, international authors became aware of the scholarship in the US and included the resultant findings in their own research, fostering international collaboration in the process. Increasingly, researchers are relying on the Internet for their resources, just as our students are. I would guess that resources available online are cited more often, to the benefit of the authors, the publishing journal, and the sponsoring organization. Let's make it a win-win game for all educators and students in technology, engineering, and design! Let's abandon the outdated paradigm and throw the doors to our scholarship wide open!

JEL

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Articles

How Taiwanese and Americans Think About Technology

Rong-jyue Fang, Chia-chien Teng, and Chih-chia Chen

The Motives

Technological changes play a key factor in social and economic development. People's knowledge, attitudes, and abilities about technology influence the choices and national development (Zhang, 1999). According to a 2005 report of the International Institute for Management Development (IMD), Taiwan ranks second in world technology competitiveness. This ranking represents the Taiwanese people's positive outlook on living in a technological world. If Taiwan wants to remain technologically competitive, it needs technology education. A quality program of education for technological literacy is expected to be beneficial to Taiwan for a variety of reasons, including the developing technological talents, upgrading economic development, solving technological problems, and facilitating social adaptation (Lee, 2004). Lee (2004) also stated that technology has not been well understood by the public. Technology educators in Taiwan realize that the more people understand about technology education, the more support they will offer to the programs. Thus, it is valuable to technology educators to understand how Taiwanese people think about technology.

The International Technology Education Association (ITEA) published two surveys completed by the Gallup Organization about how American people think about technology, one in 2002 and another in 2004. The ITEA/Gallup Polls inspired a comparison study of the Taiwan people about how they think about technology, which was accomplished in cooperation between Taiwan and

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the U.S.A. To facilitate making comparisons, the Taiwanese study used the same questionnaires (translated into Chinese) used in the ITEA/Gallup Poll.

The Context

Since 2001, Taiwan has been engaged in curriculum reform. The Ministry of Education divided all subjects into seven major fields of study. The new curriculum requires technology education in the elementary and junior high schools that is merged with the science curriculum and is entitled “Science and Technology.” This program articulates textbook content and extends across nine years of study. The technology program in junior and senior high schools has been an independent subject long before the recent reforms and was titled Living Technology as was technology education at all levels. The structure of this program is based on four main technological systems-- Energy and Transportation, Technology and Life, Construction and Manufacturing and Information and Communication. Before the grade 1-9 curriculum reform, technology education in grades1-6 was integrated into the “Arts and Crafts” and was typically taught by art teachers. Even with the latest reform, the program lacks competent teachers to teach it.

Since 2001, the credit hours of the technology education program have been almost cut in half. For example, currently there is only one class period of 45 minutes per week in junior high school. Technology teachers are finding it more and more difficult to allocate time to technology education because the “Science and Technology” is often dominated by science educators.

Purpose

This study obtained data on how the Taiwanese people think about technology and compared selected findings to the ITEA studies of 2001 and 2004. It is hoped that this research will offer recommendations for government officials and developers when revising educational programs and curriculum, especially those related to technology education.

This study relied upon an annual report of registered household demographics in Taiwan. (Ministry of the Interior, Department of Population, 2004) The Taiwanese study targeted households with individuals reaching 18 years of age by the end of 2004. These data did not include Penghu County, Kinmen County and Lienchiang County).

Methodology

Survey Instrument

ITEA published their survey data on “How American Think about Technology” in 2002 and 2004 (Rose & Dugger, 2002; Rose, Gallup, Dugger, & Starkweather, 2004), it explored the similarities and differences between these two iterations of the survey. The American survey was conducted using a telephone poll. This study could not use the same telephone method due to many telephone-based swindles in Taiwan at the time of the research. In addition, the researcher's time and money are limited. As a result, the Taiwanese study was conducted via mail. Through this processes, it can avoid some of the pitfalls of telephone polling, particularly the fact that not all potential respondents are listed in the telephone directory, either because the number is unlisted or because they do not have a telephone. A stratified random sampling was used to assure representation.

The 2004 ITEA/Gallup Poll questions were translated into Chinese. Two professors of technology education and one English teacher were consulted to keep the revision as close as the original meaning as possible. The English teacher has served as the translator for the Kaohsiung Municipal Educational Bureau and has significant experience with educational documents and questionnaire translation.

To better understand what people think about the integration of technology into other subjects, researchers added two questions (numbers 14 and 15), which originally appeared in the ITEA 2002 questionnaire. The questionnaires were mailed on February 15, 2005 and due six weeks later.

Sampling

This study used stratified random sampling. The target population was Taiwanese people 18 years of age or older and included about 17,290,000 people at the beginning of 2005. The selected samples were divided according to population ratio with consideration given to (a) geographic location (counties vs. cities) (b) gender (c) level of education, and (d) age ranges. The sampling strategy was based upon the Taiwan government's Ministry of Internal demographical data for December 2004 (Ministry of the Interior, Department of Population, 2004) and the educational data from the national census report that is conducted every ten years (Direct-General of Budget, Accounting and Statistics, Executive Yuan, 2000). The researchers calculated the percentage required in each of the strata mentioned above.

A list of junior high schools provided by the Ministry of Education was used to randomly choose two schools from each of the 22 counties and cities in Taiwan. The study group then contacted technology teachers in these junior high schools to ask them for help. The researchers sent the sampling specifications and instructions to them. The teachers were able to distribute questionnaires to the potential respondents in the sample through their students and thus their parents, relatives, neighbors, and so forth. There were 1,500 elements in the sample and usable questionnaires were received from 1121, for a response of 74.7%. The sampling procedures are described graphically in Figure 1.

Data Analysis

All data were analyzed using the Statistical Package for the Social Sciences, version 12.0. This included frequency tables (see Tables 1-18) and thus enabled direct comparison to the survey findings from ITEA (Rose & Dugger, 2002; Rose, Gallup, Dugger, & Starkweather, 2004).

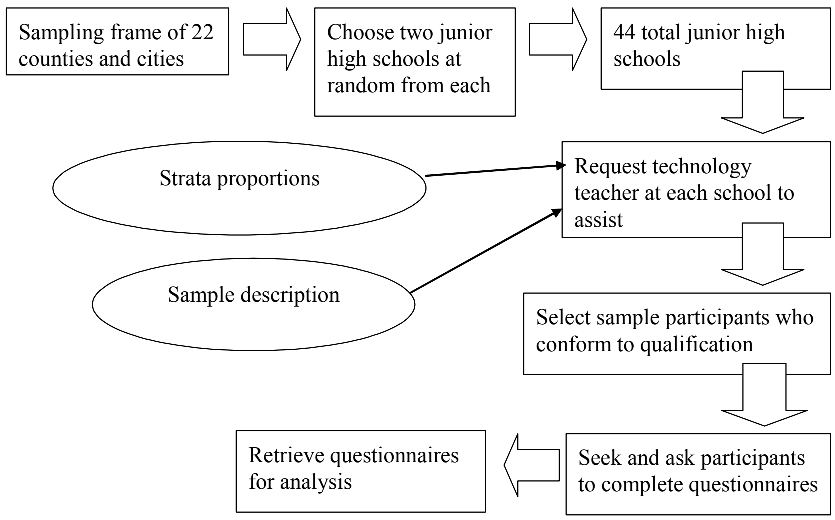

Figure 1. Sampling and data collection method.

Findings and Discussion

The findings are presented in the same order as the items on the questionnaire. The ITEA/Gallup Poll in 2001and 2004 data are compared with the current study. Some questions appeared only on the questionnaires of either the 2001 or the 2004 study, while others appeared on both. This is indicated appropriately in the tables. The questions are cross-referenced to the numbering system used in the original ITEA polls for the convenience of the reader.

Question 1 asked what people think when they hear the word "technology." In the ITEA/Gallup Poll survey, this was an open-ended question and respondents could give whatever definition they desired. In the Taiwanese survey, this question could be completely open-ended or the participants could agree with one of eight selections based on the top eight answers from respondents to the ITEA/Gallup Poll (2004).

In the ITEA/Gallup Poll findings, when the word "technology" was heard, most Americans closely associated it with "computers" and the percentages reported were 67% and 68% respectively in 2001 and 2004. It appears that Taiwanese have a broader view of technology, with less than half indicating "computers". Nineteen percent of Taiwanese chose "science," constituting the second ranking. "Internet" was third, showing that Taiwanese did not distinguish technology and science clearly and associate technology with things correlated with the computer, just as Americans did.

Table 1
Question 1: When you hear the word "technology," what first comes to mind?

	US (ITEA)		Taiwan
	2004 %	**2001 %**	**2005 %**
Computers	68	67	42.3
Electronics	5	4	7.2
Education	1	2	6.5
New Inventions	1	2	9.9
Internet	2	1	11.6
Science	1	1	19.0
Space	1	1	1.8
Job/work	1	1	0.9
Others			0.8

Question 2 asked, "Just your opinion, how important is it for people at all levels to develop some ability to understand and use technology?" In the American survey, 99 % (2001) and 98% (2004) of Americans think knowledge about technology is important compared to 92% of Taiwanese. Most of the remainder responded that they "Don't know/ refused" which implied some misunderstanding about the concept of technology.

Table 2 indicates that 86% of Americans (2004) and 89.3% of Taiwanese think that it is important to know how various technologies work while 14% of Americans and 5.5% Taiwanese feel it's unimportant.

Table 2
Question 3: How important is it to you to know how various technologies work? Is it very important, somewhat important, not very important, or not important at all?

	ITEA 2004 %			Taiwan 2005 %		
Importance	**Overall**	**Ages 18-29**	**Ages 50 +**	**Overall**	**Ages 18-29**	**Ages 50 +**
Very important	38	52	32	49.2	64.1	41.4
Somewhat Important	48	43	48	40.1	30.3	38.7
Not very important	11	5	15	5.2	0.4	10.2
Not at all important	3	□	5	0.3	0.9	0.3
Don't know/refused	□	□	□	5.2	4.3	9.7

In the items in Table 3, most Americans and Taiwanese responded similarly regarding technological abilities with one exception. On this item, 89% of

Americans versus 73.5% of Taiwanese feel it is important or somewhat important to use VCRs and other "thinking "products. The researchers found some evidence that this difference could have been caused by unclear wording of this item and consequence misinterpretation.

Table 3
Question 4: How important is it to you, personally, to know each of the following?

	Very or somewhat important		**Not very or not at all important**	
Questions 4.1~4.6	**ITEA 2004**	**Taiwan 2005**	**ITEA 2004**	**Taiwan 2005**
4.1 Knowing whether it's better to repair products or better to throw them away	93	92.7	7	3.2
4.2 Diagnosing why something doesn't work so it can be fixed	92	92.7	8	4.7
4.3 How to program a VCR or use other "thinking" products	89	73.5	11	15.8
4.4 Being able to develop solutions to a practical technological problem	89	83.7	11	9.7
4.5 How to fix a light switch or other household product that stops working	86	86.2	14	10.0
4.6 Knowing how products such as a paper stapler work	64	63.4	36	25.8

Item 5.1 stated, "Technology is a small factor in your everyday life." The majority of Americans disagreed with this while the majority of Taiwanese agreed. On the question of whether "The results of the use of technology can be good or bad" in item 5.3, the vast majority of both the Taiwanese (92.4%) and Americans (94%) agreed with this statement. On items 5.2, "Engineering and technology are basically one and the same thing" and 5.4 "Science and technology are basically one and the same thing", a significantly higher proportion of Taiwanese (11.8% and 7.8% respectively) selected "Don't know/ Refused" than the Americans (1% and 1% respectively). This showed that fewer Taiwanese were clear about the difference between engineering, science, and technology compared to Americans.

Table 4 indicates that Taiwanese and Americans have similar attitudes toward selected general statements about technology. In item 6.1, ninety-seven percent of Americans and 93% of Taiwanese agree that humans often develop new technologies to improve upon previous technologies. In item 6.2, two-thirds of Americans and three-fourths of Taiwanese agree that most environmental problems can be solved using technology, showing more confidence in technology among Taiwanese. In item 6.3, more than half of the respondents from both countries understand a fundamental concept about the design process (86.3% and 97% respectively).

Table 4
Question 6: Please tell me to what extent you agree or disagree with the following statements about technology.

	Strongly agree or mostly agree		Mostly disagree or strongly disagree		Don't know or refused to answer	
	ITEA 2004 %	Taiwan 2005 %	ITEA 2004 %	Taiwan 2005 %	ITEA 2004 %	Taiwan 2005 %
6.1 Humans often develop new technologies to improve upon previous technologies	97	93.0	3	5.6		1.4
6.2 Most environmental problems can be solved using technology	66	74.7	33	22.8	1	2.5
6.3 Design is a process that can be used to turn ideas into products	97	86.3	3	9.1		4.6

Table 5
Question 7: Based on your understanding, tell me if each of the following statements is true or false.

Questions 7.1-7.4	ITEA 2001 % True	ITEA 2001 % False	Taiwan 2005 % True	Taiwan 2005 % False
7.1 Using a portable phone while in the bathtub creates the possibility of being electrocuted	46	51	49.3	48.6
7.2 FM radios operate free of static	26	72	55.1	43.4
7.3 A car operates through a series of explosions	82	15	64.5	33.2
7.4 A microwave heats food from the outside to the inside	37	62	68.2	31.4

Question 7 required true-false responses regarding selected technological products. The questions were based on the 2001 ITEA study. About half the respondents from both countries were not sure if using a portable phone in the bathtub could cause electrocution. Americans appear to know more about, FM radio characteristics, how an internal combustion engine works, and how heating occurs with a microwave oven. These data are reported in Table 6.

Question 8 was based on the ITEA 2004 study and intended to determine whether selected statements were true or false. Unlike the ITEA 2001 which elicited a dichotomous true or false response, a four point scale was used. One of the items was very similar to the phone item in the previous question, except that "cordless" was substituted for "portable." The results for this item were very similar to the earlier ITEA study, showing that roughly half of the respondents believed that a cordless phone could deliver a lethal shock if used in a bathtub. About half of the Americans believed correctly that antibiotics were not effective with both bacteria and viruses whereas this was true for only about one-third of Taiwanese. Nearly three-fourths of Americans believed that the World Wide Web and the Internet as the same while the percentage for Taiwanese was about 10 percent less that this. The majority of respondents in both countries believed that fuel cells were being used with gasoline and diesel engines in automobiles, though this was true of slightly fewer Taiwanese.

Table 6
Question 8: Please tell me if you think the following statements are absolutely true, probably true, probably false, or absolutely false.

	Absolutely true or probably true		**Absolutely false or probably false**		**Don't know or refused to answer**	
	ITEA 2004 %	**Taiwan 2005 %**	**ITEA 2004 %**	**Taiwan 2005 %**	**ITEA 2004 %**	**Taiwan 2005 %**
8.1 Antibiotics kill viruses as well as bacteria	48	68.8	51	28.4	1	2.8
8.2 Using a cordless phone while in the bathtub creates the possibility of being electrocuted	49	49.6	49	45.7	2	4.7
8.3 The Internet and World Wide Web are the same thing	72	62.3	24	29.0	4	8.7
8.4 Fuel cells are now being used with gasoline or diesel engines to power cars	77	68.2	16	21.7	7	10.1

The next four questions related to contemporary topics and issues in technology, including biotechnology, robotics, construction, and space exploration. Table 7 indicates that Taiwanese and Americans have a strong interest in the four topics. The interest levels were very comparable with the exception that Americans have greater interest in the biotechnology area involving the modification of plants and animals relative to the food supply.

Table 7
Question 9: How much of an interest do you, yourself, have in the following topics?

	Very or somwhat interested		Not very or not at all interested		Don't know or refused to answer	
	ITEA 2004 %	Taiwan 2005 %	ITEA 2004 %	Taiwan 2005 %	ITEA 2004 %	Taiwan 2005 %
9.1 Modification of plants and animals to supply food	69	55.8	31	42.4		1.8
9.2 Robotics and other technologies in manufacturing	60	66.6	40	29.5		3.9
9.3 New construction methods or homes and buildings	74	71.9	26	25.3		2.8
9.4 Space exploration	64	63.7	36	33.8		2.5

Question 11 was a follow-up to one in 2001 in which respondents were asked how much influence that they thought they had on technological decision making in their country (ITEA, 2001 and 2004). In 2004 only 41% of Americans believed that they did have influence. On the other hand, a significantly higher proportion of Taiwanese people, 61.6%, felt that they had such influence. Taiwanese who were 50 and older felt that they more influence than their younger counterparts.

Although two-thirds of Americans reported in 2001 that they wanted a voice in making decisions about technology, two-thirds of American respondents in 2004 seem comfortable with leaving these decisions to the experts (ITEA, 2004); The 2005 Taiwanese data showed that more than 60 percent of the respondents have confidence into leaving decision making (related to fuel efficiency of cars, the construction of roads, and genetically modified foods) to experts in the field.

Questions 13 through 18 in this study asked the Taiwanese people about their opinions related to technology education in the schools. In Table 9, Americans strongly believed that technology should be included in the school curriculum (97%), while only 71.8% of Taiwanese responded this way. When those who supported its inclusion were asked if it should be a separate subject or combined with other subjects, the majority of both the Americans and

Taiwanese said it should be integrated with other subjects. However, the proportion of

Table 8
Question 11: How much influence do you think people like yourself have on decisions about such things as the fuel efficiency of cars, the construction of roads in your community, and genetically modified foods?

	ITEA 2004 %			**Taiwan 2005 %**		
Importance	**Overall**	**Ages 18-29**	**Ages 50 +**	**Overall**	**Ages 18-29**	**Ages 50 +**
A great deal	9	12	9	20.4	18.8	26.9
Some	32	37	29	41.2	39.8	40.8
A great deal or some	**41**	**49**	**38**	**61.6**	**58.6**	**67.7**
Very little	40	39	40	25.3	29.3	19.9
No influence	19	12	22	9.0	5.7	8.2
Very little or no influence	**59**	**51**	**62**	**34.3**	**35.0**	**28.1**
Don’t know or no response				4.1	6.4	4.2

Table 9
Question 13-15: Using a broad definition of technology as “modifying our natural world to meet human needs,” do you believe the study of technology should or should not be included in the school curriculum?

	ITEA 2001 %	**Taiwan 2005 %**
Yes, should be included	97	71.8
No, should not be included	3	14.9
Those who believed that the study of technology should be included in the curriculum were asked if it should be made a part of other subjects like science, math, and social studies or taught as a separate subject?		
As a separate subject	36	45.5
Integrated into other subjects	63	52.9
Those who responded that it should be taught as a separate subject were asked if it should be required or optional		
Required	51	55.3
Optional	49	42.6

Taiwanese feeling this way was just over half, considerably less than among Americans. Roughly half of the respondents in both countries believed that, if technology were taught as a separate subject, it should be required.

In Question 16, both Taiwanese and Americans agreed that high school students should know, understand, and be able to do things related to technology. Question 17 revealed that a vast majority of Americans (94%) believe that the American schools can prepare the technologically literate people through education in their own schools rather than bringing in experts from other countries, while only about three-fourths (74.4%) of Taiwanese believed that this is true. In question 18, Taiwanese (72.6%) and Americans (88%) agreed that technology should be included in the national testing programs of science, mathematics, and reading. This shows that Taiwanese and Americans believe that knowing and understanding technology is a basic literacy every person should possess.

Age as well as gender influenced the results of this study. Table 10 reports a comparison of responses regarding the importance of technology. A higher proportion of American women (75%) than Taiwanese women (57%) felt that it

Table 10
Extent of agreement with technology-related statements by gender

	ITEA %		Taiwan %	
Statement	**Men**	**Women**	**Men**	**Women**
1. It is very important to develop abilities to understand and use technology.	73	75	70	57
2. It is very important to know how various technologies work.	41	35	59	54
3. Strongly agree that technology is a small factor in their everyday lives.	20	20	17	19
4. Feel they have very little influence in decisions relating to construction of roads, new construction, and genetically-modified foods.	37	42	18	19
5. Have either a great deal or some confidence in the ability of experts to make the decisions.	67	64	66	65
6. Believe the study of technology should be part of the school curriculum.	97	99	69	68
7. Believe questions designed to determine how much students are able to understand and use technology should be included in government-mandated tests.	88	88	72	68

was important to understand and use technology. Though there were differences overall between the responses of Americans to Taiwanese as reported earlier, the differences between men and women for the remainder of the items were relatively minimal.

Table 11 breaks down by gender the responses to four sub-questions reported earlier regarding technological abilities (Question 4). Though there were significant differences between American men and women, these gender-based response differences were virtually nonexistent among Taiwanese.

Table 11
Importance of technological knowledge and abilities by gender

	ITEA %		**Taiwan %**	
Statement	**Men**	**Women**	**Men**	**Women**
1. It is very important to know whether it is better to repair products or better to throw them away.	62	67	58	61
2. It is important to be able to diagnose why something doesn't work so that it can be fixed.	67	58	56	55
3. It is very important to be able to program a VCR or use other "thinking" products	47	61	36	32
4. It is very important to be able to fix a light switch or other household product	61	45	54	52

Table 12
Importance of technology in everyday life by gender

	ITEA %		**Taiwan %**	
Statement	**Men**	**Women**	**Men**	**Women**
1.Say that antibiotics kill both viruses and bacteria is absolutely false	32	38	11	14
2.Say that a cordless phone in a bathtub creates the possibility of being electrocuted is absolutely false	37	18	33	17
3.Say that the Internet and the World Wide Web are the same thing is absolutely true	37	24	31	24
4. Say that fuel cells are used with gasoline and diesel engines to power cars are absolutely true.	36	19	45	31

Table 12 reports responses by gender about technology in everyday life. (Question 8). In general, the differences between the responses of men and women are similar between the two countries.

Table 13 reports the level of interest in technological topics by gender. Women in both countries are less interested than men in robotics and related technologies and in new construction. More American women than men are interested in plant and animal modification relative to the food supply, whereas Taiwanese men are more interested in this topic than women. More American women are interested in space exploration than men whereas the opposite is true for Taiwanese.

Table 13
Difference of the gender response in the question 9

Statement	ITEA %		Taiwan %	
	Men	Women	Men	Women
1. Very interested in knowing about the modification of plants and animals to supply food.	24	29	24	16
2. Very interested in the use of robotics and other technologies in engineering.	27	11	35	17
3. Very interested in new construction of homes and buildings.	40	30	39	24
4. Very interested in knowing about space exploration.	35	39	32	20

Summary of Similarities and Differences

Importance of Technological Literacy

Similarities: Most people in both countries think that it is important to develop technological literacy and understand the importance of technology in everyday life. Technology and computers are mistakenly thought of as the same thing.

The Impact of Technology on Daily Life and on the World

Similarities: Most people in both countries think that technology, engineering, and science are the same thing. Men tend to have more understanding than women about the technological knowledge related to daily life.

Differences: More Americans feel that technology is important in their everyday lives than do Taiwanese. Taiwanese men give more importance to developing the ability to understand and use technology

What People Want to Know and What They Know About Technology

Differences: The level of understanding of technological devices such as FM radios and microwave ovens is not consistent between citizens of the two countries: Taiwanese understand some devices better than Americans while for others the opposite was true.

Similarities: Most people have a strong interest in the modification of plants to supply food, the use of robotics in manufacturing, construction of homes, and space exploration. Taiwanese men indicated a higher level of interest in these topics than women, whereas the gender differences among Americans varied by topic.

Decision Making Regarding Technology and Technological Literacy

Differences: Americans report being better informed about space exploration than Taiwanese. More Taiwanese than Americans feel that they have influence over national decisions made about technology and older Taiwanese citizens feel more strongly about this than younger ones.

Technology and Education

Similarities: Among those who believed it should be taught as a separate subject, about half the respondents in both countries felt that it should be required. When a national shortage of qualified people occurs in a particular area of technology in a country, most people agree that the preferable option is to educate their own citizens in their own schools to fill the deficit. Most people agree that nationally mandated tests should include questions to help determine how much students understand and know about technology.

Differences: Fewer Taiwanese than Americans believe that technology should be included in the school curriculum. More Americans favored technology being integrated into other subjects. Though the citizens of both countries believe in educating their own citizens to fill needs for expertise, as mentioned above, a higher proportion of Americans felt this way.

International Comparisons

Volk & Dugger (2005) published a report that compared the first and second ITEA/Gallup poll with a similar poll conducted in Hong Kong. Regarding the importance of being able to understand and use technology, Americans were slightly more adamant (98%) than Taiwanese (92%) and Hong Kong people (93.1%). Far more Americans than Hong Kong or Taiwanese citizens equate technology with computers.

Volk & Dugger (2005) stated, “Overwhelmingly, both samples strongly supported the inclusion of technology in schools” (p. 64), while far fewer (71.8%) Taiwanese supported the inclusion. The majority of Americans and

Taiwanese indicated that it should be integrated in other subjects, however, less than half of Hong Kong people felt this way. Volk & Dugger (2005) pointed that this outcome may have been the reflected the feelings of Hong Kong citizens regarding national examinations. However, a national testing program has been ongoing in Taiwan as well and it did not seem to influence the responses. It may prove worthwhile to compare the two countries in more detail.

Conclusions and Suggestions

1. *The reduction of technological course content and teaching time in Taiwan through the latest curriculum reform is contrary to what the citizens believe and expect in developing technological literacy.*

According to the findings of this research, most Taiwanese think it is important to develop technological literacy and they believe that technology should be included in the school curriculum. Most technology educators in Taiwan believe that it is necessary to help all citizens become technological literate through technology courses in the secondary and primary schools (Lee, 2004). Though the latest curriculum reform integrated technology with science into a single course at the high school level, the two subjects are still taught separately in most schools; the two subjects are really not integrated. At the same time, the technological course content at the junior high school level is gradually being reduced. Typically there are only one or two chapters in the textbook that address technology content and the remainder are science. Most of the new "Science and Technology" courses are taught by science teachers. Technology teachers rarely have the opportunity to teach the technological content (Lee, 2004).

2. *Taiwanese are not clear about the similarities and differences between engineering, science and technology*

Most Taiwanese think that technology, engineering, and science are essentially the same. In addition, they equate technology with computers to a large extent. This deficiency in technological literacy needs immediate attention by the Taiwan government.

3. *Taiwan must assure that students know about the technology they encounter in daily life through the school curriculum.*

Taiwanese have less understanding than Americans about some of the technology they encounter in their everyday lives. The heating principle of microwaves and knowledge of antibiotics are two examples revealed by this study. Although, Taiwanese support technological literacy and agree that it is important, the educational system has not yet included technology in its national examinations. In agreement with Lee (2004), this study reaffirmed that Taiwan should provide leadership and reestablish the importance of technology education in its educational system. In addition, to better assure that Taiwanese have accurate knowledge about technology, the mass media and the Taiwanese technology education professionals should both play a significant role.

4. *There is little gender differences regarding interest in technological knowledge and the application of technology around the home.*

Taiwanese men and women responded very similarly about their interests in specific areas of technology and the use of technology within the home. This is in contrast to American men and women. A possible explanation for this is the rising level of gender equity in Taiwan. Taiwanese women are now better educated, more represented in the workplace, and enjoy a higher level of income. They are increasingly more knowledgeable about technological products such as home appliances, computers, automobiles, and so forth. Moreover, the government of Taiwan considers boys and girls to have equal needs in understanding and adapting to the rapidly changing world in which they live, resulting in some needed reforms in education. Up until about ten years ago, Taiwanese junior high school boys studied industrial arts and the girls studied home economics. Now, boys and girls study both technology and home economics. Nonetheless, more men than women felt that it is important to study technology in the schools.

Final Thoughts

This study highlights some interesting similarities and differences between Americans and Taiwanese. Certainly many of the differences may be explained by the wide variation in the two cultures, especially in societal values, historical precedents, economic bases, and educational systems. It is interesting to note, at the same time, how similar some of the results are despite the cultural disparities.

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Effects of Test Taking on Retention Learning in Technology Education: A Meta-Analysis

W. J. Haynie, III

Commencing in 1985, a small body of experimental studies on the effects of test taking on delayed retention learning of technical subject matter has been completed in technology education settings. Much of the learning in technology education courses, especially the hands-on aspects, are best assessed via instruments and techniques other than traditional tests; but classroom tests are still important for learning in the cognitive domain and the time that technology teachers spend administering tests is best spent if the tests also help students learn.

Two of the studies were completed in public schools and the others were conducted in university classes. One central question in all of the studies concerned the effects of taking tests on the delayed retention of the information tested. Delayed retention is important because that comprises the information and concepts that the student still knows three or more weeks after the effects of "cramming" for the test have evaporated—thus, delayed retention represents the important and significant learning in a technology course. Nine other related factors were examined concerning the types of tests used, time on task, and subtle variations in the setting of the experiments. A total of nine experiments were conducted over a twenty year period. One of the studies failed and the other eight had significant findings of importance in answering the research questions posed. This article reports a meta-analysis conducted by the author of the series of studies to summarize that body of work.

Background

Testing in education, including technology education, and the large amounts of instructional time it consumes are important topics of continuing research. Most of the research reported on testing has historically concerned standardized tests (Stiggins, Conklin, and Bridgeford, 1986; Haynie, 2004). Today, with high stakes testing employed to track student and school performance, this emphasis on standardized testing in the research literature continues. Most of the evaluation done in schools, however, is done with teacher-made tests (Haynie, 1983, 1990a, 1992, 1994, 1997b, 2003a, & 2004;

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Herman & Dorr-Bremme, 1982; Mehrens, 1987; Mehrens & Lehmann, 1987; Newman & Stallings, 1982). Research efforts on the effects of teacher-made tests and other issues surrounding them such as frequency of use, quality, investment of the time required to administer and return them, benefits for student learning, optimal types to employ, and usefulness in evaluation add valuable findings to the body of knowledge for educators. The available findings on the quality of teacher-made tests cast some doubt on the ability of teachers to perform evaluation effectively (Burdin, 1982; Carter, 1984; Fleming & Chambers, 1983; Gullickson & Ellwein, 1985; Haynie, 1983, 1992, 1997b; Stiggins & Bridgeford, 1985). Mehrens and Lehmann (1987) cite the importance of teacher-made tests in the classroom and their special ability to be tailored to specific instructional objectives. Evaluation through teacher-made tests in schools is an important and needed part of the educational system (including technology education classes) and a crucial area for research (Haynie, 1983, 1990a, 1992, 2003a; Mehrens & Lehmann, 1987).

Marsh (1984) reported that, despite fears of tests and distaste for them, students in an experimental study self-reported that they studied more for material which was to be tested in-class. This finding was consistent across groups—both those who had been tested in-class and those who had been tested by take-home methods reported that they learn more when facing an in-class test. Mixed findings on the anxiety caused by tests have been reported by Denny, Paterson, and Feldhusen (1964), and Marsh (1984). Several studies have demonstrated the positive effects of in-class tests on retention (Duchastel, 1981; Haynie, 1990b, 1991, 1994, 1995, 1997a, 2003a, 2004; Nungester & Duchastel, 1982). All of the studies by Haynie were completed in technology education settings with technical subject matter. Some studies have shown positive effects of reviews instead of tests on retention (Haynie, 1990a; and Nungester & Duchastel, 1982). Haynie (1995) showed some benefits of post-test reviews on retention.

Haynie (1990a) initiated a series of experimental studies to examine the issues concerning teacher-made tests and their effects on retention learning in technology education. A protocol was developed following the general methodology of Nungester & Duchastel (1982) with only those changes needed to adapt it to a technology education setting. The subject matter consisted of concepts, factual information, and applications concerning modern "high tech" materials (including composites, exotic metals, and heat shielding materials) developed or used in the NASA space exploration program. The information was presented via videotapes, including live demonstrations, script written by the researcher, excerpts from NASA "Tech Briefs" and other publications, and graphs/charts showing the relationships of various characteristics of the materials under study. Due to two unrelated factors, this first study failed to make any significant findings on the research questions posed concerning the learning effects of testing. One problem was a weakness of the 20-item test instrument used to collect the data and the other was failure of teachers to follow important directions crucial to the design of the study. The teachers were instructed to isolate participants from distracting activities nearby in their regular open-space lab by using another room pre-arranged by the researcher. Instead, half of the teachers showed the videotapes and administered the tests in the open-space lab while other groups worked on project construction activities—thus greatly confounding the experiment. Though there were some non-significant trends in the data from the teachers who had cooperated, overall there were no significant findings about the research questions posed. This study had some unrelated serendipitous findings concerning difficulties in presenting effective instruction in open-space environments which were reported in a minor journal (Haynie, 1990a). This study is not included in the meta-analysis presented here. Its importance, however, is that it laid the groundwork for the later successful investigations. The 30-item version of the instrument that resulted was used for the entire series of studies that followed. Eight successful experiments were then conducted and reported (Haynie 1990b, 1991, 1994, 1995, 1997a, 2003a, 2003b, and 2004). This meta-analysis examines the key findings of those eight studies.

Methodology of the Experiments

The protocol for the experiments, as approved by the university human subjects review panels (first at George Mason University and then at North Carolina State University) involved the initial instruction of all groups, a test or no-test treatment, a three-week delay period, and a final unannounced delayed retention test on the same information. Initial instruction in the first two efforts (conducted in public schools) was via a videotape developed by the researcher and his graduate students. All of the other studies were conducted in university classes with instruction via printed text materials. In the text-based studies, the information on "high tech" materials and their applications was presented in a booklet developed by the researcher that included original text, excerpts from NASA "Tech Briefs" and other publications, graphs/charts, and discussion of civilian applications of the materials studied. The booklet included a table of contents, text, halftone photographs, line drawings, and a full index to make it parallel with any regular course textbook. In the earliest studies all participants were informed that their scores on initial tests (if given) would not count in their course grade because the unit was newly added to the course and final materials were still in development (Haynie, 1990b, 1991, 1994, and 1995). This factor was criticized by reviewers of the early studies who questioned whether students had taken the unit of study seriously and had actually "given a good, honest effort" as requested during the directions for the unit. Therefore, some of the same questions were revisited in later studies (Haynie, 1997a, 2003 a, 2003b, and 2004) in which all students knew from the start that their grades would be affected by any tests taken in the unit (except, of course, the unannounced delayed retention test which was still voluntary and used for research purposes only).

The delayed retention test had 30 items. Twenty of these items were alternate forms of the items used in initial tests for those groups who were initially tested. The remaining ten items comprised a subtest of novel information used to determine if students studied the entire booklet or simply hunted for the answers via the index (in cases where take-home tests were used or study questions were provided). Those ten items were interspersed so that students would not perceive them differently from the original twenty. The tests operated chiefly at levels 1-3 of Bloom's taxonomy: Recall of facts, conceptual understanding, and application of learning to novel situations. Each level was represented equally. The delayed retention test scores were the only data analyzed to answer the research questions.

Another factor criticized in some of the early studies concerned assurance of equality in ability of the groups participating. In the earliest studies (Haynie 1990a, 1990b, 1991, 1994, and 1995) random assignment was the only technique used to assure equal ability in the groups. Each experimental group was comprised of several intact class sections combined together to form one group. This technique provided an adequate *n* for the experiments to have acceptable power and also reduced the likelihood of extraneous variables such as time of day, semester, teacher (graduate assistant) conducting the class, or other factors from systematically affecting any particular experimental or control group. Since the course sections generally enrolled 20 or fewer students, two to four independent sections (randomly assigned) were required to make each experimental or control group (ranging from 35 to 71 depending upon how many groups were compared in each study). In all studies the *n* for the groups compared within a particular experiment was very similar.

The researcher felt that this randomization process was adequate assurance of equal entering ability among groups. However, following the advice of the most critical reviewers, in the final four studies (Haynie, 1997a, 2003a, 2003b, and 2004) the researcher demonstrated equality via a related "metals pretest" administered immediately before the experiment began. The study topic in the experiment involved high-tech and composite materials, so the metals pretest (covering the unit studied just prior to the experiment) was viewed as an adequate indicator of equal ability. In none of those experiments was a difference found in entering ability for either the experimental or control groups.

Normal precautions were taken to assure adequate lighting, temperature control, quiet atmosphere, limited distractions, and other comfort and privacy factors to provide an acceptable test environment. All directions concerning participation in the studies were read from prepared scripts to avoid confounding factors. The delayed retention test was carefully prepared and evaluated with reliability ratings between .69 and .74 for various studies within the series using Cronbach's Coefficient Alpha. According to Thorndike and Hagen (1977), tests with reliability approaching .70 are within the range of usefulness for studies of this type. All study materials were collected following the initial two-week instruction period and were maintained in secure storage to prevent advance information for future groups of students. In a debriefing session following the experiment, students were requested not to share any information about the experiment, its methods or purposes, or the unit of study with their peers.

The factors involving the types of test or no-test conditions, use of study questions or reviews, and exactly what was announced prior to or during study of the unit of information were the various treatments in the investigations (independent variables) and the performance on the delayed retention test was the common dependent variable in all of the experiments. This consistency allows reasonable comparison of results in this meta-analysis. Readers who desire more specific details about the treatments used in any particular study are encouraged to read the original reports as published.

Methodology of the Meta-Analysis

The methodology of this meta-analysis involved calculation of the "Effect size" (Δ) for each factor of interest in all studies which examined that factor (Borg & Gall, 1989). The effect size was found using the formula:

$$\Delta = \frac{\overline{X}_{Exp} - \overline{X}_{Con}}{SD_{Con}}$$

Once the effect sizes were determined, they were also averaged with consideration of the *n* of each mean to find a weighted "Mean effect size". The Effect sizes, Mean effect sizes, and Number of positive findings are reported for ten research questions of interest in Table 1, following procedures used by Mayer and Moreno (2002) in a similar effort. The remainder of this report examines the composite findings on these research questions.

Findings

Ten questions were considered in the eight experimental studies. All of the studies sought answers to two of those (generalized) questions:

- Does taking a test increase retention learning? (Factor 2 on Table 1), and
- Does time on task (including tests) increase retention learning? (Factor 3).

The remaining 8 factors (1, 4, 5, 6, 7, 8, 9, and 10) were only considered in one or two studies each. There were significant positive findings on six of the eight remaining related research questions with only factors 1 and 5 having no supportive significant findings. There were slight non-significant positive trends supporting factors 1 and 5. Discussion of each of the research questions and the studies which examined them follows.

Factor 1: Does prior knowledge of an upcoming test increase retention learning?

In the two experiments in which a group was told to expect a test but they did not actually receive a test, they showed only slightly higher achievement on delayed retention vs. groups told they would not be tested (Haynie, 1990b,

Table 1
Effects of Tests on Retention Learning: Meta-analysis of Eight Experimental Studies.

	Findings & Sources	**Effect size Δ**	**Mean effect size**	**Number of positive findings†**
1	Prior knowledge of upcoming tests increases retention learning		0.05	2 of 2
	1990b	0.01 NS		
	1997a	0.09 NS		
2	Taking a test increases retention learning		0.76	8 of 8
	1990b	0.54 *		
	1991	1.10 *		
	1994	0.90 *		
	1995	1.29 *		
	1997a	1.57 *		
	2003a	0.67 *		
	2003b	0.17 NS		
	2004	0.26 NS		
3	Time on task (including tests) increases retention learning		0.85	8 of 8
	1990b	0.60 *		
	1991	1.10 *		
	1994	0.90 *		
	1995	1.29 *		
	1997a	1.57 *		
	2003a	0.67 *		
	2003b	0.40 *		
	2004	0.26 NS		
4	Take-home tests support retention learning		0.58	2 of 2
	1991	1.08 *		
	2003b	0.08 NS		
5	Take-home tests support retention better than in-class tests		0.10	2 of 2
	1991	0.05 NS		
	2003b	0.14 NS		

† Both significant findings and non-significant positive trends included in this column
* Indicates a significant difference found
NS Indcates no significant difference

Table 1 (continued)
Effects of Tests on Retention Learning: Meta-analysis of Eight Experimental Studies.

	Findings and Sources	Effect size Δ	Mean effect size	Number of positive findings†
6	Take-home tests only support retention of material actually appearing on the tests		0.47	2 of 2
	1991	0.17 NS		
	2003b	0.76 *		
7	Short-answer tests support retention learning		0.66	1 of 1
	1994	0.66 *		
8	Post-test reviews support retention learning			1 of 1
	1995	0.34 *		
9	Matching tests support retention learning		0.90	1 of 1
	2003a	0.90 *		
10	Study questions support retention learning		0.85	1 of 1
	2003b	0.85 *		

† Both significant findings and non-significant positive trends included in this column
* Indicates a significant difference found
NS Indcates no significant difference

1997a). This seems counter intuitive because one would assume that students study more diligently when they expect a test than when they do not—the anticipation of an upcoming test would logically drive students to study. It may well be true that immediately after instruction occurred, the groups who expected a test would have had more immediate knowledge in short term memory (having "studied up" for the expected tests). But that was not the point of these experiments; this research concerned delayed retention (defined as learning lasting 3 weeks after instruction). Though there was a very small amount of positive trend favoring the groups who thought they would be tested over those who knew they would not be tested, it appears that no significant amount of meaningful learning was achieved merely because of the anticipation of a test. In both of these studies, however, Factor 2 clearly shows that students who actually did take the announced test did retain significantly more information following the three-week delay period. So, the mere threat of an upcoming test does not increase retention learning unless a test is actually administered.

Factor 2: Does taking a test increase retention learning?

This was the most important factor of consideration in all of the experiments examined. Six of the eight experiments had significant positive results of varying magnitude supporting the premise that taking a test increases retention learning. In the other two studies there were non-significant trends supporting this premise as well. It appears that, regardless of the type of tests used, the act of taking a test helps move information from short term memory to a deeper level. Whether this effect is caused by the mere fact that taking a test provides one additional opportunity for rehearsal or there is some unknown factor (such as the kinesthetic act of writing the answers) at work was not determined by this series of studies and that may be a fruitful topic for further investigations.

Factor 3: Does time on task (including tests) increase retention learning?

This showed positive significant findings in all but one of the studies (Haynie, 2004) and logically follows the findings on Factor 2. In addition to test taking (any type of test), both reviews and use of study questions were shown to aid in retention. The one study that failed to have significant findings on this issue did show a supportive non-significant trend. This finding is in harmony with those in a broad spectrum of the research literature in education—time on task does support both short term and retention learning.

Factor 4: Do take-home tests support retention learning?

The findings on this factor were mixed. The 1991 study had a high positive and significant finding while the 2003b study only supported take-home tests with a very slight non-significant trend (nearly neutral). These research questions were answered on the basis of the total 30-item delayed retention test results. The two subscales within the tests (previously tested information, and novel information) were used to investigate Factors 5 and 6.

Factor 5: Do take-home tests support retention better than in-class tests?

The 1997a study included a simple survey in which students claimed that they prefer take-home tests (80%) but they admitted that other types of tests were more accurate for evaluation (77%). Some students say they learn more with take-home tests but that claim was not fully supported in these experiments. Both of the studies that examined this question (1991 and 2003b) had slightly positive non-significant trends in support of take-home tests over in-class tests on the whole. But closer examination of the findings in these studies on the subtests of previously tested and novel information showed that these gains were entirely due to higher performance on the previously tested information while their performance was actually lower on the novel information. To fully sort out the meaning of this finding Factor 6 must also be examined.

Factor 6: Do take-home tests only support retention of material actually appearing on the tests?

The findings in both of these studies on the subtest of novel information (information that was not reflected on either the in-class or take-home versions of the immediate test) showed that the in-class groups outperformed the take-home groups. In the 1991 study, this was only a non-significant positive trend, but the 2003b study had a clear positive significant finding showing that the groups who were tested in-class had studied the material more fully while the take-home groups had apparently merely hunted for the answers to the specific questions appearing on their take-home tests.

Factor 7: Do short-answer tests support retention learning?

The only study examining this factor (1994) had a positive significant finding. In that study, however, the groups who took multiple-choice tests scored even (significantly) higher than the short-answer test groups.

Factor 8: Do post-test reviews support retention learning?

Only the 1995 study asked this question and it had a significant positive finding. Teachers who invest the time to return tests and review them with students provide additional time on task in addition to the reinforcement value this practice affords. The following quotation from the 1995 study set the stage for this investigation:

> One aspect of testing which has received little attention in the literature is the usefulness of post-test reviews. After a test is administered and scored, the instructor typically returns the test to students or provides knowledge of results so that students can see their progress in the course. If the test is actually returned, students may be allowed to ask questions about items they missed, the instructor may review the entire test, or no additional information may be given. Reviewing the entire test is time-consuming, but it may be a justifiable use of class time if significant retention learning occurs due to the review. Alternatively, if retention learning is not enhanced by post-test reviews, then they are a waste of valuable class time. Some researchers have questioned the value of in-class tests and asserted that assignments done at home and other sorts of time on-task work could be equally or more beneficial in promoting learning (Faw & Waller, 1976; Haynie, 1990[b]; Gay & Gallagher, 1976). For those who hold this view, post-test reviews would seem an inexcusable waste of valuable learning time. (Haynie, 1995, p. 80)

The gain shown in this study was beyond the gains already documented from anticipating and then taking a test because the Effect size of .34 was found by contrasting the group that took a test and then had the review against the group that only took the test. By reexamining Factor 2 (in Table 1) it may be seen that both of these groups had already outscored the no-test control group by a high significant Effect size of 1.29. It would not be legitimate to combine these two Effect sizes by merely adding them, but it is clear that if taking the test results in an Effect size of 1.29 and then there is a further increase due to the post-test reviews as documented by the .34 Effect size favoring the review group, the combined benefits of a test followed by a review are considerable.

Factor 9: Do matching tests support retention learning?

Yes, the 2003a experiment had a significant positive finding which showed that matching tests do support retention of the information tested. In fact, in this single study, there was even a small significant difference in the scores of the two tested groups which favored the matching test group over the multiple-choice test group, but the actual difference in the means of the scores was so small that it would be of no practical significance. No claim for superiority of matching tests was made in the conclusions of this study—both matching and multiple-choice tests were reported to support retention learning.

Factor 10: Do study questions support retention learning?

The study that considered this question used two groups with the exact same treatment but with different names. In the 2003b study, one of the groups took the take-home test and another group was given the same exact set of questions with the heading "Study Questions." They were not told that other groups had the same information as was on the take-home test. When tested three weeks later, the group with the study questions outperformed all of the other groups (even the in-class test group) despite the fact that they were not actually tested. It is presumed that these students, unlike the take-home test students, did in fact read the entire study booklet, studied it broadly, and then used the study questions as an aid to further review and study. They did expect that a test was forthcoming, but they were not actually tested, so they likely prepared as well as the in-class test group or (apparently) better.

Conclusions and Recommendations

Ten factors were examined in this series of eight related experiments. The methods of the studies were similar except for the treatments related to immediate testing. The dependent variable in all of the studies was a delayed retention test that was common to all groups in all of the studies, enabling clear comparisons among the studies. The instructional materials and tests all concerned technical subject matter about "high tech" materials used by NASA and their applications beyond the space program. The tests went beyond mere memorization of facts to also represent levels 2 and 3 of Bloom's taxonomy: Comprehension and Application. All ten of the factors were found to have some supportive findings, though for two of them the support was merely non-significant trends in each. The remaining 8 factors all had at least one study with a significant supportive finding. No negative findings were present. The ten factors and the findings related to them are discussed fully in the preceding section of this article.

The most persuasive evidence among the eight studies was support for the hypotheses that taking a test on material studied and increased time on task (whether in the form of a test or other activities such as reviews or use of study questions) both result in increased retention learning by students. Even given the hands-on nature of much of the learning in technology education courses, the cognitive learning is best assessed with traditional classroom tests and it is important to maximize the learning value of the time spent in testing. Further, delayed retention learning, as evaluated in these experiments, is of far more value than the short term recall evidenced when students take a test for which they have recently "crammed." If all of the findings of this meta-analysis and the individual studies are considered together, it would appear that the best practice for increasing retention learning of students would be a well orchestrated protocol in which:

1. An upcoming in-class test is announced at the time the unit of study commences.
2. Study questions reflecting about 2/3 of the test are provided. The study questions should be alternate versions of the actual test items they reflect.
3. The test should be administered as promised.
4. In the first class session following test administration, the test should be returned after it has been graded and a thorough post-test review should be conducted in which students see their scores and are allowed to ask follow-up questions about items that they missed.

This recommended procedure does require a lot of class time and diligence by the teacher to grade tests as soon as possible after they are given. It is also understood that some students may become alienated or even argumentative if they feel that ambiguous or "tricky" items have harmed their score and their eventual course grade. Though such moments would be uncomfortable, the prudent teacher will then follow the recommendations in previous works (Haynie, 1983, 1992, and 1997b, or any text on test construction) to improve the weak or flawed items for the benefit of future students. These and other previous studies have shown that teacher-made classroom tests, though valuable for many reasons, often have serious flaws. Only when well prepared tests are administered properly, graded quickly, and reviewed effectively will the maximum gains in retention learning be achieved by students. This is a large investment of time and effort by both teachers and students, but if learning is not aided by testing, the testing itself is a waste of resources and time. Only important cognitive learning should be treated in this thorough manner, but if facts, concepts, or abilities to apply learning to novel situations are truly important for accomplishing technology course objectives, this holistic approach will enhance the likelihood of students retaining what they learn.

Future studies in this vein should examine questions related to instruction and testing via computers, testing issues in distance learning settings, and follow-up investigations to determine what it is about taking a test that supports retention. Perhaps there are ways to further enhance those particular elements or actions that support the retention learning gains more efficiently. Testing will remain a value-charged issue worthy of future research. At present there is a trend toward the evaluation of many more learning products and activities via rubrics and other means that draw attention away from traditional tests. Nonetheless, classroom tests will remain a very prominent feature of education (including technology education) for the foreseeable future and educators should invest the time to use them well.

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Children as Innovators in Action – A Study of Microcontrollers in Finnish Comprehensive Schools

Esa-Matti Järvinen, Arto Karsikas, and Jouni Hintikka

In authoritative teaching methods, whereby the teacher controls the social interaction and other classroom activities, the actions of many children are often in response to what they perceive to be the teacher's expectations and the requirements of traditional school evaluation practices, such as examinations and tests (Edwards & Mercer, 1987; Vygotsky, 1997, p. 126). In this kind of school setting, children do not necessarily feel the teaching and its content to be personally important or useful. For this reason, it is difficult for them to make meaningful connections between what they are taught and their everyday life. To make learning more authentic and meaningful to children, it is essential to give them a sense of ownership for their learning (Savery & Duffy, 1995). As epitomized by Biesta (1994, p. 315), it is important that the "contribution of the child is not a pseudo-contribution that is totally dependent upon the intentions and activities of the teacher." In this regard also, von Glasersfeld (1995, p.14) wrote aptly "[p]roblems are not solved by the retrieval of rote-learned 'right' answers. To solve a problem intelligently, one must first see it as one's own problem." Moreover, it is important that children be able to work in an atmosphere which is low in stress and allows concentration on the task at hand (Futschek, 1995).

Since technology can be seen as a response to "satisfy human needs and wants" (Black & Harrison, 1985; Dugger & Yung, 1995; Savage & Sterry, 1990) and as human innovation in action (see ITEA, 2000), teaching methods in technology lessons should be adjusted accordingly. Problem solving is also considered essential in a technological process (e.g., McCormick, Murphy, Hennessy, and Davidson, 1996).

In technology lessons the problems to be solved should relate to children's real life environment, allowing them to make appropriate and meaningful connections (Schwarz, 1996). Children should be given opportunities to explore and pursue their own needs and interests. They should be encouraged to identify problems and deficiencies in their everyday environment and be given

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opportunities to apply the technological knowledge and skills they have acquired in technology lessons and through previous problem-solving experiences (Adams, 1991).

Study Purpose

The overall purpose of the study was to help children become familiar with some essential features of microcontroller technology and its possibilities in various aspects of everyday life. Moreover, the study essentially aimed to encourage children to engage in innovative thinking in finding uses for microcontrollers to meet their own needs and purposes. More specifically, the study involved the following:

Give children opportunities to learn about the human-made environment (technology).

In accordance with this aim, an effort was made to enhance the children's understanding of the human-made environment "such as it is." This aim is close to the goals of most school subjects, where teaching aims to increase understanding about the world at large. In this respect familiarization with microcontrollers and their programming introduced a very contemporary content area to technology education.

Give children opportunities to engage in the processes of technology, i.e., to design, make, and apply technology in a creative and innovative manner

This aim could also be exemplified in the definition: "Technology is human innovation in action" (ITEA, 2000). If the "message" of this definition is the basis for teaching technology, it cannot merely involve the study and consideration of the functional principles of microcontroller technology as an end in itself. Children need to be given opportunities for creative and innovative action as well. This is why the study aimed to focus on the innovative uses of microcontrollers in applications that arose from the pupils' own needs and ideas. Ultimately, the study was directed toward this question: What type of microcontroller applications emerged in the children's own projects?

Study Methodology

Instructional and Research Context

The study reported herein was carried out within a European Union-funded research and development project in technology education at the University of Oulu. It was the first study in Finland to introduce the teaching of microcontrollers in primary schools. The microcontroller system used in the study is based on the Picaxe-08 system developed in England by Revolution Education Ltd. (see www.rev-ed.co.uk/picaxe) and it was modified collaboratively with a Finnish company, Step Systems Ltd., so that it could be better applied to the pedagogical aims of the study. The Finnish Association of Graduate Engineers (TEK) provided support in the purchase of materials and equipment for the study.

The participants consisted of both primary and secondary school teachers who had been taking part in the Technology Education *NOW!* project over a period of years. All project schools were supplied with information about a microcontroller called the "Picaxe" and associated activities. Over 50 teachers were contacted and given the opportunity to participate and 12 elected to do so. The study was carried out during school years 2003-2005.

First, the Picaxe-08 system was introduced to the teachers by arranging a two-day in-service training course. The course consisted of both theoretical and practical aspects of microcontrollers with a special emphasis on the Picaxe-08 system. Another focus of the training was the programming software. Importantly, the teachers were also encouraged to make their own innovative Picaxe applications and this pedagogical advantages of doing so was also emphasized. This perspective was emphasized for the teachers to take into account within the forthcoming Picaxe project with children.

Second, Picaxe software and hardware, including components for children's applications, were sent to the participating schools. Instructions for introducing the microcontroller system to the children were included in the Picaxe package.

The Picaxe-08 system shown in Figure 1 is a relatively new kind of tool for applying microcontrollers in an educational setting and is based on the 8-pin PIC (Peripheral Interface Computer) integrated circuit chip. While programming, children can design the functions desired by means of a flowchart or by using the BASIC language, after which the program is downloaded with a serial cable to the microcontroller on the project (circuit) board. To enable children's innovativeness, a special project board was designed for the study (see Figure 1). First, the children constructed a project board using instructions and diagrams provided (Figure 2). However, the project boards were just 'starting points' and used to familiarize the children with the Picaxe materials before actually beginning the design activity (Figures 3-7). In the end, the idea was that the children could design, make, and program an application rising from their own ideas and needs. To enhance thinking of different possible applications, a wide variety of components were sent to the schools. These included light emitting diodes (LEDs), buzzers, lamps, motors, sound recording modules, miniature water pumps, as well as sensors such as various kinds of switches, passive infrared sensors (PIRs) as well as negative temperature coefficient (NTC) thermistors and light dependent resistors (LDRs). The software is available free of charge from the manufacturer and most of it has been translated into Finnish. One important feature of the Picaxe system is that children can reprogram the device repeatedly, designing new and improved applications to their liking.

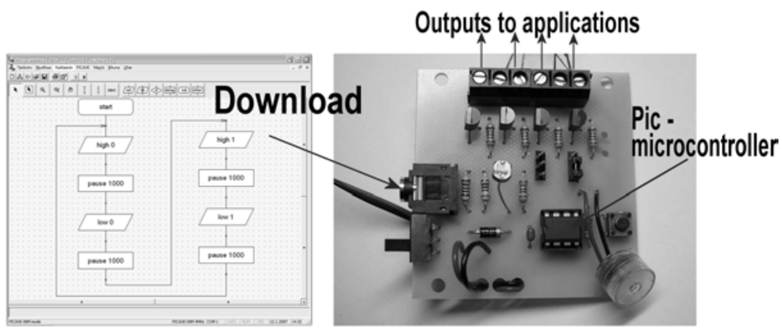


Figure 1. The flowchart software and project board used in the study

Figure 2. The project board being assembled (left) and being tested (right).

Study Participants

Twelve comprehensive (primary and secondary) school classes of grades 5-8 (ages 11-14 years) participated in the study. The number of children involved was 230. The participating schools were located in Oulu Province: Järvikylä School in Nivala, Oksava and Martinmäki Schools in Haapajärvi, Vattukylä, Hyttikallio and Karhukangas Schools in Haapavesi, Ruukki School in Ruukki, Kestilä Central School in Kestilä, Matkaniva and Petäjäskoski Schools in Oulainen, Lintulampi School in Oulu and Kärsämäki Central School in Kärsämäki. All the participating schools were state schools, which is the predominant comprehensive school system in Finland.

Data collection

True to the qualitative data collection methods, multiple data sources and strategies were employed, applying the concept of triangulation (Miles & Hubermann, 1994: 266). Data were collected in the following ways: Pictures taken of the children working while making the Picaxe applications, teacher's written reports, researcher's notes of the process and applications, children's written and drawn sketches of their applications, photographs and video clips of the children's final outcomes, as well as interviews of children documented on video recordings. The interviews were carried out in authentic situations where children explained their applications. The questions asked from the children emerged spontaneously from the situation. Thus, the interviews were not pre-structured and, consequently, there was no "standard" time that they lasted either. Moreover, not every child was interviewed. Some of the children's applications called for more explanation than others. For example if the teacher told the researchers that not all the essential information of the child's application were to be found in the sketches, drawings, etc., an interview session was arranged to deepen the understanding of what the child had actually done and accomplished.

Data Analysis

During the first round of analysis, the researchers began to form an idea of the emergent categories relative to the theme of this study. In subsequent analysis rounds the data revealed more organized patterns relative to the research question. During the analysis process, the researchers were continually open to re-exploring the relationship between the data and emergent findings and making revisions correspondingly. They discussed and shared thoughts on several occasions. The data examples presented in this article were considered individually and also in the collaborative discussions (see Ritchie & Hampson, 1996). Finally, the researchers reached the stage where they considered to have investigated the entire body of data sufficiently relative to the research problems. Once the researchers reached the "saturation point" with the data, efforts were redirected to presentation of the results and related analysis.

Results

The categories presented in the Table 1 are the result of going through the data several times and searching for emerging patterns. The categories indicate that the systems the children designed and built with the Picaxe were rather varied. Even within one classroom there was a rather large variation in what children made for their Picaxe application (except in the case of Amusement Park Devices, Hydro-Copters and Race Cars). This is an interesting phenomenon in itself, for children tended to be rather independent in pursuing their own idea.

Table 1
Categories and examples emerging from the data

Categories and Examples			
Modeling Existing Devices	**Everyday Needs**	**Competition**	**Just for Fun or Decoration**
Amusement park devices	Burglar alarm systems	Race cars	Joe-boy, the talking parrot
Traffic lights	Presents for mother		Fountain
Hydrocopters	Name plates using LEDs		Music applications
Low light sensor	Sound recording module		Map of Finland with LEDs
	Fish feeding system		Logo of the ice-hockey team with LEDs
			Small bushes/trees with LEDs

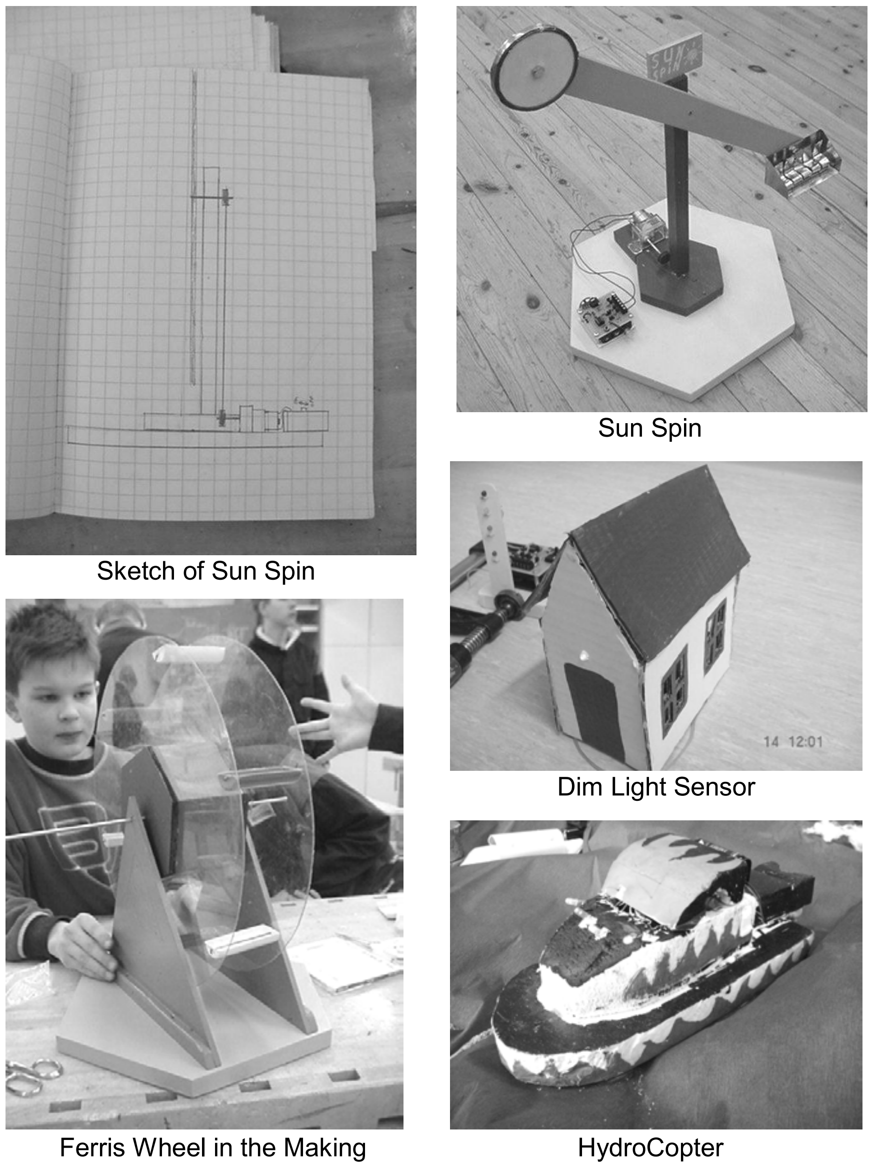


Figure 3. Examples of modelling existing devices (1)

Amusement Park

Figure 4. Examples of modelling existing devices (2)

Modeling Existing Devices

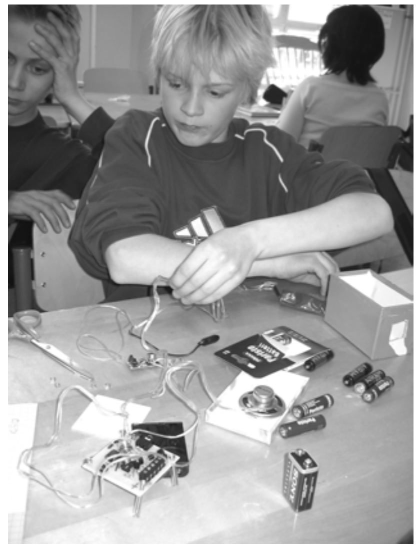
Some students modeled existing devices. For example, most of the amusement park devices shown in Figures 3 and 4 are what would be found in actual amusement parks. The children have seen them while visiting the parks and modeled the devices accordingly. The other applications, like traffic lights and hydro-copters, involved the same idea of modeling something that already exists. Even though the dim-light sensor shown in Figure 3 has the obvious idea of practical need, it can be regarded more as a model of the existing device, for it was not meant to be used as a “real thing.”

There was also an innovative bias in some of the applications in this category. For example, designing the light control system for hydro-copters, and figuring out how to make it function properly inspired children to be problem-sensitive and even innovative. But, the overall process started with the willingness to make miniature models of existing devices. Thus, doing something which would be a response to emergent needs and purposes was not a primary motive.

Meeting Everyday Needs

Programming an LED Flower

Presents for Mothers' Day



Making a Burglar Alarm

Figure 5. Examples of projects designed to meet everyday needs.

Excerpts from Video Clips

Excerpt 1 – In reference to Burglar Alarm in Figure 5.

Researcher:

Could you tell me how came up with that idea?

Child:

We came up with this idea…because some unidentified visitors had visited our hut in the woods….and the teachers told us that we'll do these things [microcontroller systems] I got an idea that I can make a kind of alarm system….and actually it has served the need pretty well…

Researcher:

Could you tell me how it works?

Child:

[showing the alarm system to the researcher] here is the on/off switch....and here is a sound recording module on which you can record whatever you want to say….and when the system is activated …and when it [passive infrared sensor] identifies somebody moving…the system switches on the [LED] eyes and plays the recorded message, "unauthorized access denied!"

Excerpt 2- In reference to Sound Recording Module

Teacher:

OK, could you tell me what that is?

Child:

If I'm not at home….somebody can leave a message on it [Sound recording module] by pushing a button and when I come home I can listen to the message.

Teacher:

Yes… that is useful.

This category includes more innovative applications which tend to be responses to needs and purposes identified by the children. It was essential among these ideas that the children wanted to solve a practical problem arising from their personal living environment such as the burglar alarm system illustrated in Figure 5 or a fish feeding system. Importantly, the applications were tested in the actual situation in which they were intended to be used. If the application, such as the burglar alarm system, did not function properly it was modified and tested again.

Although there already are many burglar alarm systems in the environment in which the children live, they did not copy these existing systems. Instead they connected components into the applications supplying their own needs, as was the case in "Unauthorized access denied!" In Excerpt 1 the child (12 year old 6th grader) explained both the problem which 'ignited' the technological process and the principle upon which the system operated. In Excerpt 2 the response of the child (12 years old 6th grader) reveals the starting point for the process of performing the application with the Picaxe. It is analogous to a modern version of writing a quick message on a paper. Though the on-site interviews exemplified by the two excerpts above were not conducted with most students, they did provide some details that would not have otherwise been known.

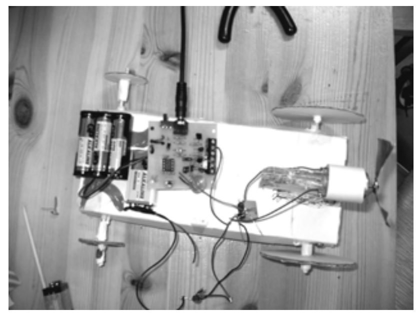
Presents for mother are made every year in Finnish schools, but the Picaxe project and associated materials took the students in a different direction from the greeting cards typical of the past. Some of these new ideas are shown in Figure 5. Importantly, the process started by doing something that would actually operate in response to the needs and purposes identified by the children themselves. This in itself is an important notion and makes creating the technological application real for the student instead of contrived as many school projects can end up being. It is a technological solution that they created even though the hardware and software they used already was in use in "the adults' world." (Savery & Duffy, 1995)

Competitions

Despite concerns to the contrary, competitions do seem to be very useful in teaching technology. When competing with each other, children tend to be very motivated and focused in problem-solving. For example, if they do not have the fastest race car, they are motivated to see how they can make it perform better.

Race cars model elements in the real world. However, children are not limited in their thinking to duplicating what already exists. For example, some children supply motive power using propellers instead of using the traditional idea of supply power to wheels. See Figure 6. The creativity of the student can be enhanced and expanded by how the problem is stated. For example, if the problem is to build the "fastest device" instead of the "fastest car," children tend to think differently.

Finishing touches being added to race car

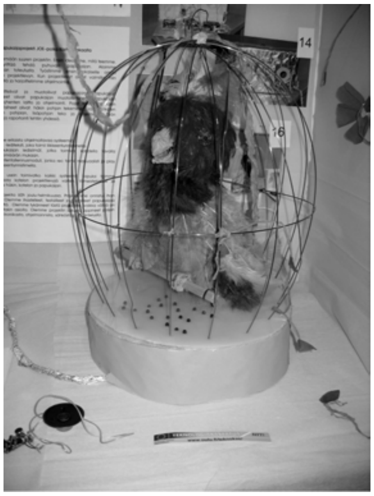


Program downloading to micro-controller chip

Figure 6. Projects designed for competition

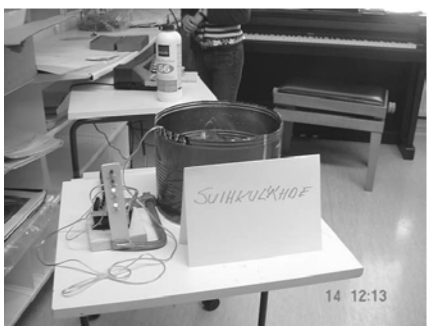
Just for Fun or Decoration

The last category that evolved included projects that were "just for fun" or served decorative purposes. The applications in this category are shown in Figure 7. They did not directly correspond to the children's needs and purposes emerging from their own living environment. At the same time the researchers recognized the need for children to have beautiful and fun things in their environment. In that sense, the projects met the needs of the children. For example, the map of Finland with certain cities highlighted with LEDs has some practical value, but this was not substantiated in either the teacher's report or in other data sources. Moreover, the applications in this category were not intended to just model something already existing. When having fun, children may invent a new, different and even innovative use for technology as well. Joe Boy – The Talking Parrot (see Figure 7) was awarded third place in a national research and invention competition for children in May 2005

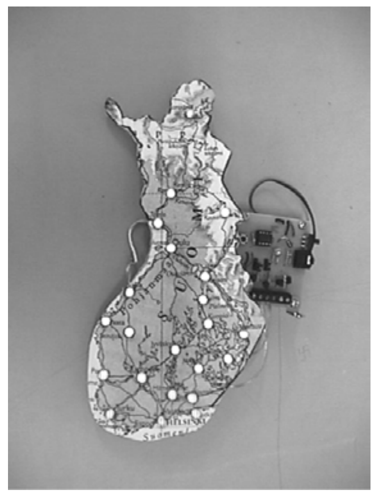


Joe Boy, the talking parrot

Proud creators of Joe Boy



Water fountain



LED map of Finland

Figure 7. Projects designed for fun alone

Discussion

The Picaxe teaching experiment was not really designed pedagogically to teach students how microcontrollers work, as would typically be the case in the upper grades. Instead, the emphasis was on helping students realize their own ideas and needs by applying microcontroller technology in a creative and innovative manner. Moreover, the Picaxe teaching was not directed by traditional school evaluation practices. Even the teacher did not necessarily know what kind of applications the children would eventually create. One of the teachers wrote, “For the first time, there was an electronics project whose final product was not known by anyone at the start of the project. When they were putting the project board together, the pupils acquired information and skills on basic issues in electronics (components, soldering, etc.), but at the same time they were constantly thinking about the subsequent application and its various possible uses". In spite of the openness of the Picaxe activity, some children had a tendency to copy and mimic the ideas of other children. This raises the question of what is appropriate in the support and encouragement of children to "trust" their own needs and ideas and to take the risk to pursue them. Such risk taking is not often rewarded in traditional school situations. The worry of failure, negatively reinforced by prior experiences in school, may have cause some students to copy ideas from others. At the same time, it does not mean that every student should be expected to be an innovator. The important thing is that each student be able to pursue ideas that meet their personal needs, and those needs might be satisfied from copying a project idea from another student.

This study confirmed once again that children have very fertile minds for coming up with unique ideas. Educators and other adults must make every effort to consider the ideas of children seriously and with encouragement. One never knows when the ideas of children could lead to new kinds of applications and innovations. Ultimately, every effort should be made to assure that a child's experience with technology education positive, builds confidence, and results in directly experiencing "human innovation in action" (ITEA, 2000). The study also reinforced the notion that technological understanding and problem-solving ability is a unique kind of human intelligence (Chen, 1996).

Innovation is not just something carried out in the research and development laboratories of large technology industries, but all of us, including children, can be innovators. As a result of the ongoing research, the authors repeatedly reaffirm that one of the most serious pitfalls of technology education is to underestimate the ability of children to be creative and innovative in technology. As Barlex & Pitt (2000, p.12) stated, "being 'technological' is part of what makes us human."

The possibility to change the human-made world empowers children in a way not usually experienced in schoolwork. Interestingly, this echoes Piaget's thoughts of the principal purpose of education being to encourage children to do new things and not just repeating what previous generations have done – to inspire them to be creative, inventive and discoverers (Piaget, 1970).

Conclusion

In technology education it is important to engender the idea of how the human-made environment has developed and is still developing through human activity. Ingenuity, innovation, and problem solving are part of the basic essence of technology (e.g. Sparkes, 1993; Järvinen & Hiltunen, 2000; Järvinen, 2001). Consequently, in technology lessons it is essential to also enable children to have ownership of their designing and making processes. The researchers observed that many of the children who took part in the study acted in accordance with the idea put forward by Adams (1991):

> Successful inventors that I know are extremely problem-sensitive. They are tuned to the little inconveniences or hardships in life that can be addressed by the technology they know. (p. 87)

If a child is able to identify a problem and proves to be successful in solving it in a way that the solution meets personal needs, it results in a very positive experience. It is "serious business" to the child and importantly, in the process he/she goes through the processes truly reflective of technology (Layton, 1993).

It is natural and, in some cases imperative, to provide technology education through an integrative approach that cuts across subject boundaries. The "Human and Technology" theme in the new Finnish curriculum framework is an example. Technology is multidisciplinary by nature and cannot be limited only to applied science or handicraft skills.

In technology lessons, the doing and its understanding are most important. Teaching technology should not begin with the introduction of conceptual jargon, but with design challenges that enable children to come across the underlying technological principles spontaneously while engaged in the learning activity (Papert, 1980).

The authors advocate that children's understanding of technology can be achieved by enabling them to work in the same spirit that real technologists do. This approach brings authenticity to the experience. It is also essential that children are encouraged to work and learn in a way that fosters creativity and discovery. This can be facilitated in an atmosphere that is low in stress and enable children to concentrate on their own problems (Futschek, 1995).

In closing, the authors wish to encourage teachers who are not already doing so to try an open-ended approach to technology teaching. More work and preparation is required, along with open-mindedness and the courage to deviate from the normal school routines, but the rewards are worth the effort. When the final outcome of children's problem solving processes is unknown to them, boredom and disinterest is replaced with thrilling anticipation (Järvinen & Hiltunen, 2000).

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The Relationships of Spatial Experience, Previous Mathematics Achievement, and Gender with Perceived Ability in Learning Engineering Drawing

Ahmad Rafi and Khairul Anuar Samsudin

Taking advantage of the convergence of technology and new insights of teaching and learning, the Ministry of Education of Malaysia has implemented a new educational reform primarily to revise the current curriculum, establish new learning standards, and incorporate the use of technology as an integral part of the learning process. This new educational reform suggests more of a focus on critical-thinking processes, problem solving, and student assessment deemed critical in academic curricula (Custer, Valesey, & Burke, 2001). One of the critical knowledge domains that received much attention is technical education. Several educational initiatives were drawn and implemented with special focus on the integration of computer technology in the curriculum of technical and vocational teaching and learning. Engineering Drawing for example, became one of the critical subjects that drew the Ministry's attention at the secondary education level due to the fact that overall performance began to decline after 1994 as more non-technical students enrolled in public schools and began taking the same course (Nor Fadila & Widad, 1999). Similar results were reported by Jayasree's (2003) study that indicated lower performance in Engineering Drawing compared to other technical courses. As a result, a thorough investigation is needed to identify the underlying factors that contribute to this problem and find the ways and means to address it. Research on the impact of engineering drawing learning in Malaysia has generally been scarce due to the relatively early adoption of the curricula. However, studies have begun to emerge that concentrate on Malaysian secondary schools and are shedding some light on the implementation of technology courses, particularly Engineering Drawing, focusing on the pedagogical, and socio-cultural aspects (Ismail, 2002; Nor Fadila & Widad, 1999; Tuan Zaidi 2002; Widad & Hatta, 2001; Yusri,

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1997). These researchers concurred that a basic understanding of fundamental concepts of projection theory, orthographic projection, isometric drawing, hidden views, and sectional views was problematic to most learners due to poor spatial ability. In addition, the ability to grasp these topics is critical as it represents the fundamentals of Engineering Drawing that deal with the construction of 2D and 3D geometry, and the creation of multi-view and pictorial representations (Bertoline & Wiebe, 2002; Olkun, 2003).

Apart from the spatial issue, gender and mathematics achievement were also found to be factors affecting students' performance in Engineering Drawing. Nur Fadila and Widad (1999) found male students performed significantly better than their female counterparts based on a research report of Engineering Drawing courses (LPMK: LK-1998). The same study revealed better performance of students with greater previous mathematics achievement over those with lower previous mathematics achievement. A strong positive correlation between mathematic achievement and spatial ability has been established in some research (Pallrand & Seber, 1984; Siemankowski & MacKnight, 1971; Tartre, 1990). Consistent and substantive gender differences favoring males have been found for spatial tests (Linn & Petersen, 1985; Voyer, Nolan, & Voyer, 2000). These gender differences pose potential threats to the success of female students in technical, scientific, and mathematics courses. A study by Scales (2000) indicated a slight relationship between gender and achievement in introductory engineering graphics, with females having lower final grades.

From the social-cognitive perspective, Hutchison, Follman, Sumpter and Bodner (2006) surveyed 1,387 first-year engineering students, studying their self-efficacy or perceived ability. They found that low self efficacy is related to learners' confidence, motivation, and persistence, thus affecting academic performance. In a related study, again of engineering students, a significant correlation was found between students' perceived ability (self-efficacy) and spatial ability (Towle, Mann, Kinsey, O'Brien, Bauer, & Champoux, 2005). In today's egalitarian society that advocates educational equality, it is expected that students enrolled in an engineering drawing course will be drawn from diverse cultural, educational and demographic background that may affect the learning and teaching process.

Purpose of Study

The purpose of this research was to examine factors that may influence students' perceived ability or self-efficacy to learn Engineering Drawing at the foundation year, namely in the Form Four level of the Malaysian secondary schools. The school system in Malaysia consists of primary and secondary levels: the former spans over a period of six years and the latter seven years. Students in Form Four of the secondary school level are equivalent to the tenth graders of the North American school system.

The Engineering Drawing course covers a two-year period, with fundamental concepts, theories, and techniques covered during the first year and advanced topics covered during the second year (11th grade). Several factors have been identified to be critical in shaping students' perceived ability to learn the subject matter. The first year of the Engineering Drawing course involved nine topics or units and for the purpose of this research it was divided into several categories in order to study the varying perceptions of students relative to the topics they were studying. Three hypotheses were formulated from prior research to address the issues mentioned above:

1. High spatial experience students will have higher perceived ability than low spatial experience students to learn Engineering Drawing.

2. High mathematics achievers will have higher perceived ability than low mathematics achievers to learn Engineering Drawing.

3. Male students will have higher perceived ability than female students to learn Engineering Drawing.

In addition to the above hypotheses, the study also sought to identify the factor(s) among the three variables that may have a strong predictive power to explain the variation in the perceived ability of students when learning the subject.

Method

Participants

A total of two hundred and twenty four (224) students, including 75 females and 149 males of Form Four level (10th graders) taking the Engineering Drawing course at the foundation year participated in the study. The average age for all the respondents was 15 years. The sample reflects typical gender distribution in schools, with males being the majority of those in taking technical subjects such as Engineering Drawing. The percentages of students based on geometrical location were 29.3%, 25.3%, 24.4%, and 21.0% drawn from northern, southern, central, and east coast states respectively in Peninsular Malaysia, providing a balanced representation in terms school geographic locations.

Instruments

A questionnaire designated as the Student Questionnaire (SQ) was designed by the authors to elicit information regarding students' demographics and background, including mathematics achievement at Form Three level (ninth grade) and their perceived ability to learn the nine topics of Engineering Drawing. One item for each of the nine topics was designed using a Likert-type scale with choices of extremely easy, easy, difficult, and extremely difficult, with numerical responses from 4 to 1 respectively. The summation of the scores across the nine items represented an index of the perceived ability of the student to learn the content of the Engineering Drawing course. The higher the score, the higher the perceived ability of the student.

The Cronbach Alpha was calculated to estimate internal consistency, resulting in coefficients of .79, .80, .71, and .67 for perceived ability to learn all topics, high spatial content topics, orthographic and isometric topics, and low spatial content topics respectively. The reliability coefficient for the low spatial content topics was slightly below the threshold of .70 it was deemed acceptable in accordance with psychometric theory (Nunnaly, 1978).

The spatial experience of the participants was measured using the Spatial Experience Questionnaire (SEQ)and was adapted from the English version designed by McDaniel, Guay, Ball, and Kolloff (1978). The SEQ consisted of a list of twenty-five spatial activities such as drawing, map reading, and playing chess. Students were asked to rate their participation in these spatial activities on a Likert-type scale of four options: "never," "occasionally," "often," and "very often." Values from 1 to 4 respectively were assigned to the four response possibilities. An index of spatial experience was thus determined by summing the responses, the higher the score, the higher the level of spatial experience. Internal consistency for the Spatial Experience Questionnaire (SEQ) was determined by the same procedure described above and resulted in a reliability coefficient of .89. The level of spatial experience reflects the degree of spatial visualization skills.

Data Collection

Application to conduct educational research study in public schools in Malaysia entails communication with the Education Ministry's agencies, namely the Education Planning and Research Department (EPRD) and State Educational Departments (SEDs). The former requires a draft of the research proposal prior to approving the study and the latter requires a formal letter of clearance from the former to allow such study at the selected schools. Principals of the selected schools were contacted by mail upon getting the approval letter from the SEDs. The administration of the survey questionnaires was carried out by visiting the schools during break sessions or free hours to prevent disruption of school activities. Normal school and co-curricular activities and other school priorities cropping up at the last minute hampered the effort to conduct the survey on a larger scale. Nonetheless, the sample adequately represented a balanced proportion in terms of gender and geographical distribution.

The administration of the questionnaires was carried out in the presence of the second author at the selected schools to enable the collection of first-hand information on the educational setting. All the participating schools possessed similar instructional materials, gender composition, teacher-to-student ratio, and teaching experience. The educational settings were deemed to be equivalent, thus minimizing the potential internal threats to the validity of the study.

This study employed a quantitative survey approach using two questionnaires. The first instrument was designed to collect demographic and background information of respondents. The second instrument included the nine items mentioned earlier to measure the students' perceptions about the difficulty of the Engineering Drawing course.

Prior to pilot testing, the questionnaire was reviewed by a panel of experts consisting of two lecturers from the same institution where the second author is working. These individuals have extensive experience in engineering graphics and computer-aided design (CAD) instruction. In addition, one of the experts was also the author of an Engineering Drawing textbook used by students at the secondary schools. These experts were consulted to categorize the nine topics of the Engineering Drawing course into two main groups: the topics that were deemed either high spatial or low spatial in their content. It was assumed that spatial content was directly related to the degree of effort students needed applying spatial visualization skills when learning the topics. No instrument was found that would measure this variable and the categorization was purely based on the panel's opinions.

Topics considered to have high spatial content were Sketching, Geometry, Orthographic Projection, Isometric Projection, Computer Aided-Design (I), Auxiliary Views and Oblique Drawing. Topics deemed having low spatial content were Introduction to Engineering Drawing, and Lettering and Lines. Because of their importance in the actual production of drawings, Isometric Projection and Orthographic Projection were treated separately. In the end, the categories included these two plus high spatial content topics and low spatial content topics. Thus four criterion variables were set for the regression analysis.

Analysis Procedures

Spearman rank-order correlations were computed between the variables of perceived ability to learn, gender, previous mathematics achievement, and spatial experience. Multiple regression was used to analyze the data using perceived ability to learn as criterion variable and gender, previous mathematics achievement, and spatial experience as the predictor variables. A stepwise regression procedure was also run using the same initial variables to identify critical factors(s) with significant predictive power that can explain the variation in the perceived ability.

Results

Perceived ability of students to learn each unit of the Engineering Drawing course at the foundation year is reported in Table 1 in descending order of rating. The higher the reported average rating the easier the respondents perceived their ability to learn a particular topic. Students were found to have the highest and lowest perceived ability to learn *Introduction to Engineering Drawing* and *Auxiliary Views* topics respectively.

The *Computer Aided Design* topic was perceived to be the second most difficult unit to learn. It was plausible that the low perceived ability was partly attributed to students having to work with the CAD software itself, which required familiarization with an environment completely different from the realm of the manual drafting practice that they normally encounter. This

Table 1
Rating of perceived ability to learn the topics of Engineering Drawing

Topics	Average Rating	Spatial Categorization	Learning Categorization
Intro. to Engineering. Drawing	3.41	Low	Easy
Lines and Lettering	3.23	Low	Easy
Sketching	3.22	High	Hard
Geometry	2.92	High	Hard
Oblique	2.60	High	Hard
Isometric projection	2.59	High	Hard
Orthographic projection	2.57	High	Hard
Computer Aided Design	2.54	High	Hard
Auxiliary views	2.40	High	Hard

Note: Higher rating implies higher perceived ability to learn the Engineering Drawing topics

particular topic is concerned with two-dimensional drafting using AutoCAD 2000. It requires students to learn basic commands and functions to produce 2D engineering drawings. Other topics that were categorized as highly spatial, namely *Orthographic projection, Isometric projection* and *Oblique Views* were perceived to be relatively difficult as expected. The first two topics were very important as they formed the basis of an engineering drawing (Bertoline & Wiebe, 2002; Olkun, 2003). Skills in this area were deemed highly pertinent by practitioners and educators (Barr, 2004) despite the current focus on computer-aided design based on 3D modeling over manual drafting practice. Table 2 presents Spearman rank-order correlations on perceived ability to learn the four levels of Engineering Drawing topics with gender, spatial experience, and previous mathematics achievement.

Table 2
Spearman rank correlations between perceived ability, spatial experience, previous mathematics achievement, and gender.

	Perceived ability to learn based on topics.			
	All topics	**High Spatial Topics**	**Orthographic/ Isometric**	**Low Spatial Topics**
Spatial Experience	.438**	.449**	.419**	.311**
Previous Mathematics Achievement	.285**	.278**	.272**	.226**
Gender	.140*	.218**	.187**	-.042

**$p<.01$, *$p<.05$

For all topics grouping, the correlation for perceived ability to learn and spatial experience was moderate and statistically significant, *r(222)*=.44, *p* =.002. High spatial experience respondents tended to have greater perceived ability to follow the engineering drawing instructions. A low correlation was found for perceived ability and previous mathematics achievement, *r(222)*=.29, *p* =.005. High mathematics achievers tended to have greater perceived ability to learn all topics in engineering drawing. A weak correlation was found between gender and perceived ability, *r(222)*=.14, *p* =.045.

For the high spatial content category, the correlation for perceived ability and spatial experience was moderate, *r(222)*=.45, *p* =.002. This indicates that the ability to learn these topics was positively perceived by those with high level of spatial experience. Previous mathematics achievement was slightly correlated with perceived ability to learn these topics, *r(222)*=.28, *p* =.007. The correlation for perceived ability and gender was also low, *r(222)*=.22, *p* =.009.

Similar pattern of associations was replicated for Orthographic and Isometric projection topics. A significantly moderate correlation was established for perceived ability and spatial experience, *r(222)*=.42, *p* =.005. Those with higher spatial experience tended to have greater perceived ability to learn these two important topics. The correlation for perceived ability and previous mathematics achievement was low, *r(222)*=.27, *p* =.009. A weak correlation was found for perceived ability to learn these two topics and gender, *r(222)*=.19, *p* =.009.

For low spatial content topics, the correlation between perceived ability and spatial experience was significantly small, *r(222)*=.31, *p* =.004. A significantly low correlation was detected for perceived ability and previous mathematics achievement, *r(222)*=.23, *p* =.007. The correlation of perceived ability and gender was observed to be negligible, *r(222)*=-.04, *p*>.05. The negative correlation is an indication that females had greater perceived ability than males in learning topics lacking in spatial contents although the correlation was not significant.

Inter-correlations between predictor variables were also investigated revealing a moderate correlation between spatial experience and previous mathematics achievement, *r(222)*=.38, *p* =.009. A moderate correlation was

Table 3
Inter-correlations between measures

Measures	**1**	**2**	**3**
1. Spatial experience	—	.376**	.339**
2. Previous mathematics achievement		—	.162*
3. Gender			—

***p*<.01, **p*<.05

found between spatial experience and gender, *r(222)*=.34, *p* =.009. The correlation of previous mathematics achievement and gender was weak, *r(222)*=.16, *p* =.041.

Multiple regressions with the three predictor variables were conducted and summarized in the following tables. The analysis of multiple regression for the statistical model employing the scores on perceived ability to learn all topics of Engineering Drawing as the criterion variable revealed a reasonable fit (R^2 = 27.5%) and the overall relationship was significant ($F_{3,220}$ = 27.77, p<.001) as shown in Table 4.

Table 4
ANOVA for model with independent variables regressed on all topics of Engineering Drawing

Source	***SS***	***df***	***MS***	***F***	***p-value***	***R²***
Regression	864.896	3	288.299	27.770	.000	.275
Residual	2283.943	220	10.382			
Total	3148.839	223				

With other variables held constant, the scores on perceived ability to learn all topics of Engineering Drawing were positively related to spatial experience, and to previous mathematics achievement. Female students tended to have higher scores than their male counterparts on the perceived learning of all topics. The effect attributed to spatial experience was the highest (t_{220} = 7.17, *p* < .001) followed by marginal significant effect due to pervious mathematics scores (t_{220} = 2.07, *p* < .05) as shown in Table 5. The gender factor did not reveal any significant effect for this model of analysis.

Table 5
Regression analysis coefficient for model employing all topics of Engineering Drawing

	Non-standardized Coefficients		**Standard coefficients**		
	B	**Std. Error**		***t***	***p*-value**
Constant	13.446	1.888		7.121	.000
Spatial experience	.155	.022	.469	7.167	.000
Previous Mathematics Achievement	.056	.027	.129	2.070	.040
Gender	-.188	.485	-.024	-.387	.699

Subsequent examination using stepwise multiple regression confirmed that spatial experience and previous mathematics achievement were statistically significant in explaining the variation in the perceived ability to learn all topics of Engineering Drawing. The statistical model employing the perceived ability to learn topics of high spatial content as the criterion variable revealed a reasonable fit ($R^2 = 28.2\%$) with significant overall relationship ($F_{3, 220} = 28.84$, p<.001) as shown in Table 6.

Table 6
ANOVA for model with independent variables regressed on high spatial content topic

Source	*SS*	*df*	*MS*	*F*	*p*	*R²*
Regression	495.281	3	165.094	28.842	.000	.282
Residual	1259.273	220	5.724			
Total	1754.554	223				

With other variables held constant, the scores on perceived ability to learn high spatial topics of Engineering Drawing were positively related to spatial experience and to previous mathematics achievement. Male students tended to have higher scores than their female counterparts on the perceived ability to learn these topics. Spatial experience was found to be the only factor with a significant effect ($t_{220} = 7.01$, $p < .001$) as shown in Table 7.

Table 7
Regression analysis coefficient for model employing high spatial content topics

	Non-standardized coefficients		Standard Coefficients		
	B	**Std. Error**		***t***	***p***
Constant	6.808	1.402		4.856	.001
Spatial experience	.133	.016	.456	7.014	.000
Previous Mathematics Achievement	.036	.020	.112	1.807	.072
Gender	.337	.360	.057	.936	.350

This was confirmed by a follow-up stepwise multiple regression revealing insignificant effects attributed to previous mathematics achievement and gender factors in explaining the variation in perceived ability. The statistical model employing perceived ability to learn orthographic and isometric demonstrated a reasonable fit ($R^2 = 25.1\%$) with a significant overall relationship ($F_{3,220} = 24.6$, p<.001) as illustrated in Table 8. It was clear that these two topics relied heavily on the spatial experience factor that produced the only statistically significant effect ($t_{220} = 6.6$, $p < .001$). Simple main effects attributed to previous mathematics achievement and gender were not found to be statistically significant as summarized in Table 9.

Table 8.
ANOVA for model with independent variables regressed on orthographic and isometric topics

Source	*SS*	*df*	*MS*	*F*	*p*	R^2
Regression	82.453	3	27.484	24.604	.000	.251
Residual	245.757	220	1.117			
Total	328.210	223				

Table 9
Regression analysis coefficient for model employing orthographic and isometric topics

	Non-standardized coefficients				
	B	Std. Error	Standard coefficients	*t*	*p*
Constant	1.291	.619		2.084	.038
Spatial experience	.047	.007	.438	6.599	.000
Previous Mathematics Achievement	.017	.009	.118	1.871	.063
Gender	.039	.159	.015	.248	.805

A follow-up stepwise multiple regression sustained the above finding where effects attributed to previous mathematics achievement and gender factors in explaining the variation in the perceived ability to learn these two topics were determined to be insignificant. A statistical model employing perceived ability to learn low spatial content topics as the criterion variable was analyzed by multiple regression. It revealed a poor fit (R^2 = 15.5%), but the overall relationship was significant ($F_{3,220}$ = 13.42, p<.001) as shown in Table 10 .

Table 10
ANOVA for model with independent variables regressed on low spatial content topics

Source	*SS*	*Df*	*MS*	*F*	*p*	R^2
Regression	65.198	3	21.733	13.424	.000	.155
Residual	356.159	220	1.619			
Total	421.357	223				

With other variables held constant, the scores on perceived ability of learning these topics of Engineering Drawing were positively related to spatial experience factor, and positively related to previous mathematics achievement.

Table 11
Regression analysis coefficient for model employing low spatial content topics

	Non-standardized coefficients		Standard coefficients		
	B	Std. Error		*t*	*p*
Constant	6.638	.746		8.902	.000
Spatial experience	.042	.009	.350	4.960	.000
Previous mathematics achievement	.020	.011	.124	1.846	.066
Gender	-.525	.191	-.180	-2.740	.007

Interestingly, female students tended to have higher scores than their male counterparts on the perceived ability to learn these topics. Effects attributed to spatial experience ($t_{220} = 4.96$, $p < .001$) and gender ($t_{220} = -2.74$, $p < .05$) were found to be highly significant. However, the effect of previous mathematics achievement was not significant at the .05 level. Follow-up analysis by stepwise multiple regression revealed similar results confirming the poor fit of this statistical model.

Discussion

Findings from the study have provided several insights concerning the perceived ability of students to learn the subject matter of engineering drawing. Spatial experience was found to be a significant factor, having a substantial relationship with students' perceived ability to learn Engineering Drawing for all four categories of topics, thus confirming the first hypothesis of the study. Students with more spatial experience perceive that they will be able to learn the content of the course.

Prior mathematics achievement was found to have a weak relationship in predicting students' perceptions on their ability to learn Engineering Drawing content overall. Thus the second hypothesis was only weakly supported.

The notion that males would have a higher perception about their success in Engineering Drawing, the third hypothesis, was not supported. Females were found to have a higher perception than males about learning the topics, especially the low spatial content group. One plausible explanation is the notion that, in general, females have greater ability to study content that requires a learning approach based on memorization and recall of facts rather than spatial skills. This is characteristic of verbal learners, and females have been shown to be the better verbal learners and males better spatial learners (see Gurian & Stevens, 2005).

Interrelations among the variables revealed that gender factor was moderately correlated with spatial experience factor and slightly correlated with previous mathematics achievement, favoring male subjects. Similarly, previous mathematics achievement showed a moderate relationship with the spatial experience factor. A person with a relatively higher level of mathematics achievement would likely reflect a corresponding higher level of spatial experience. No cause-effect relationship, of course, is implied.

Combining all the variables and their interactions together, a pattern emerged suggesting that, in general, male participants tended to have a spatial experience and mathematics background favorable to their perceived success in Engineering Drawing. Thus males felt more positive about their ability to learn Engineering Drawing compared to their female counterparts, especially for the high partial content topics.

Spatial experience was found to be the only factor showing a significant effect in the analysis for all four categories of the criterion variables. Little of the variance in perceived success of low spatial content was explained. This was not unexpected as the loading of the spatial factor in predicting perceived ability to learn engineering topics of low spatial content was too small to be accounted in the statistical analysis. Learning these topics normally requires rote learning and recall of facts and techniques and does not rely on cognitively processing spatial information.

The other two predictor variables, gender and previous mathematics achievement, minimally accounted for the variation in the perceived ability of students to be successful in Engineering Drawing. Stepwise regression further attested to the predictive power of spatial experience over the other two factors.

The above findings can help improve current instructional methods in Engineering Drawing by recognizing the potential differences in perceived ability to learn arising from several background factors, especially spatial experience. Teachers and instructors need to be aware of these differences among individuals or groups to undertake appropriate and necessary teaching strategies in their classrooms. Another important finding was the revelation of substantial gender difference in spatial experience. In general, female students were less spatially experienced than males, which may negatively experience their performance in Engineering Drawing in which high spatial visualization skills are required. Female students may come into the course disadvantaged because of their lack of spatial experience. These students may be highly vulnerable to threats to success caused by anxiety or fear. Teachers should be aware of these potential differences in their classrooms and take action to better assure that females have a potential for success that is equal to males.

Extreme care was taken to reduce any internal and external threats to the study following the administration of the questionnaire. As stated in the method section, one of the authors was present during the data collection process to assume consistency. Confidentiality and anonymity were assured to the students and it was made clear that their participation was voluntary. It was believed that the students felt more comfortable in reporting their experience without prejudice. Thereby, systematic bias and random variance was reduced. Nonetheless, it should be emphasized that the findings were purely based on self-reporting and they have to be interpreted with caution.

Conclusion

The research findings have highlighted that almost all topics of Engineering Drawing consist of highly spatial content that require greater spatial visualization ability. Teachers and instructors may have to prepare extra or extended classroom activities in the teaching process, especially in dealing topics that are considered difficult by some of the students. Interventional programs should be planned and readily implemented in classroom activities. These include providing remedial activities to allow struggling students to expand their spatial experience and thereby increase their spatial ability.

Several research studies in addressing students' lack of experience in spatial activities through interventional programs have been demonstrated to be considerably efficacious in enhancing spatial skills. These include mental rotation (Khairul & Azniah, 2004; Turos & Ervin, 2000) and spatial visualization (Rafi, Khairul, Abdul, Maizatul, & Mazlan, 2004; Olkun, 2003), both of which have been widely recognized to be important in learning in scientific and technical fields. These novel and innovative tools provide opportunities for learners to engage specific spatial tasks, focusing on spatial visualization skills and reasoning, making them more proficient in problem solving.

A broader implication of students' perceived ability to learn is linked to its important role in all cognitive theories of motivation involving constructs such as self-efficacy. Bandura (1986) described this construct as individuals' confidence in their ability to control their thoughts, feelings, and actions and thus influencing outcomes. The lower their perceived ability to learn, the higher the risk that their confidence and motivation in the learning process will be reduced. This, in turn, may translate into poor performance. In this context, it is critical that students' motivation in the process of learning Engineering Drawing be given due attention and monitored by teachers and instructors to ensure that they experience success.

The standard practice by Malaysia's school administrative bodies to impose relatively high previous mathematics achievement at Form Three level of secondary school system (i.e. ninth grade) for entry requirement may not adequately address the low passing rate in Engineering Drawing. In addition to this requirement, the spatial experience of students wishing to take the course may have to be measured as part of the selection process.

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Identifying the Paradigm of Design Faculty in Undergraduate Technology Teacher Education in the United States

Scott A. Warner, Laura Morford Erli, Chad W. Johnson, and Scott W. Greiner

Davis, Hawley, McMullan and Spilka, in the book *Design as a Catalyst for Learning* (1997), repeatedly made reference to the "growing evidence that design is a powerful tool for transforming curriculum and accommodating the variety of ways in which students learn" (p. xiv). This acknowledgement of the importance of design as a means for promoting a diverse learning environment within a dynamic curricular setting has manifested itself through the ideals expressed in the *Standards for Technological Literacy* (*Standards*)(ITEA, 2000). This important document has firmly established for the profession of technology education the role of design as a tool for both investigating and developing the technological world.

The research that is documented here is the second part of a multi-year study that is investigating the status of design in the undergraduate experiences of future technology education teachers. These studies were designed to measure the nature of the academic/experiential infrastructure for preparing future technology educators to interpret and use the design process as part of their normal teaching strategies. Each part of this multi-year study was designed to be descriptive in nature. The first part of the study documented the types and numbers of design-focused courses offered at colleges and universities across the United States in technology teacher education programs (Warner & Morford, 2004).

The current study investigated the paradigm of the design faculty in the programs identified in the initial research. This component was designed to provide additional insight into how technology teacher education was being influenced by both the design paradigm and the demographics of the instructors of undergraduate design-focused courses.

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Through a cascading effect, the design instructor's paradigm has broad consequences for both his or her students and the profession. When pre-service technology educators graduate and move into their careers they take with them their own set of design experiences, experiences that were influenced by the design paradigms of their college instructors. Furthermore, as each new generation of teachers enters the profession, their design paradigm also influences the nature of technology education and the broader cultural perception of technological design as they teach that subject to children in grades K-12.

The Purpose for the Research

"Children learn not only the lessons which we try to teach them, but also lessons which by their very nature are perhaps more subtle" (Kennedy, 2004, ¶1). This statement by Kennedy summarizes the rationale for investigating the paradigm of design faculty in undergraduate technology teacher education in the United States. The young men and women who are studying to become technology education teachers in the K-12 classrooms of America receive two types of messages from their instructors in undergraduate courses. One type of message is clear and obvious and is brought out in the content of the curriculum, lessons, and activities that are used in a course. The second type of message is subtle and determined by factors that are completely outside of the student's awareness and control. Goodlad (1984) referred to these subtle messages as the "implicit curriculum" (p. 197). The author defined implicit curriculum as:

> . . . all those teachings that are conveyed by the ways the explicit curriculum is presented-emphasis on acquiring facts or solving problems, stress on individual performance or collaborative activities, the kinds of rules to be followed, the variety of learning styles encouraged, and so on. The implicit curriculum includes also the messages transmitted by both the physical setting for learning and the kinds of social and interpersonal relationships tending to characterize the instructional environment. (p. 197)

One source for the implicit curriculum within the design-focused courses offered to pre-service technology educators originates from the design paradigm of the course instructor. The instructor's design paradigm includes such shaping events as his or her own education, work experiences, hobbies, technical training, workshops, and conference sessions. These experiences influence how an instructor interprets and interacts with design and technology. They also affect how an instructor teaches undergraduate students, and how those students eventually teach their K-12 classes. The literature provides numerous examples of studies showing that instructors, especially student teachers and teachers who are new in their careers, tend to teach the way they were taught (Hooper, n.d.; Lortie, 1975; Goodlad, 1984; Britzman, 1991; Hansen, 1995). This behavior pattern is categorized as a component of the processes of teacher socialization. In a summary of the relevant literature on this topic, Zeichner and Gore (1990) (citing the work of Danzinger, 1970), defined teacher socialization as the process of transforming an individual into "a participating member of the society of teachers" (p.329). The process of teacher socialization is especially important to an inexperienced teacher. It helps an individual to begin establishing the infrastructure of his or her teacher identity and the professional and collegial support systems that facilitate the teaching process. With the passage of time and the development of experience in the craft, many teachers eventually move beyond rigid adherence to the models of teaching upon which they patterned their early professional experiences. However, some do not, though all carry with them throughout their career at least residual beliefs, assumptions, and behavior patterns that influence their teaching at a subconscious level (Lortie, 1975; Goodlad, 1984; Britzman, 1991; Hansen, 1995).

Zeichner and Gore's (1990) review of the literature on this subject of teachers teaching the way they were taught revealed many facets of this behavior pattern. For the purposes of this study, the researchers felt that three of those trains of thought were most relevant. The first line of consideration investigated the influence of individual role models toward shaping a novice educator's teaching attitude. The second line of consideration explored the influence of institutional factors in shaping and modifying novice teachers' attitudes and beliefs. The final line of consideration was the influences on novice educator's attitudes about teaching from other sources.

Over the last several decades the world of technology education has emerged from a transition out of industrial arts. Any major cultural change, such as this, will inevitably result in a period of uncertainty and adjustment for the members of that culture. The transition to technology education has resulted in a number of uncertainties, for both the profession and its practitioners, about the content and the methodologies that should be used to teach about technology. Arguably, the most significant effort to provide clarity and direction toward the study of technology has been the *Standards* (2000). The *Standards* embraced technological design, in its many forms, "…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). Such a statement seems rather clear about the importance of the role design should play toward the study of technology. However, the question of the nature of how *design itself* should be interpreted is still left open. On this matter the *Standards* sought to address the question with the following passage:

> Designing in technology differs significantly from designing in art. Technological designers work within requirements to satisfy human needs and wants, while artists display their mental images and ideas with few constraints. Additionally, technological designers, such as engineers, are concerned with the usability and desirability of a product or system. As a result, efficiency is a major consideration in technological design, while beauty or appearance of the product is often less important. In artistic design, by contrast, aesthetics and beauty are central issues, while efficiency is not. For those who appreciate them, technological designs can be viewed as works of art that showcase creativity equal to a well-crafted poem or an inspired painting. Industrial design may strike a balance between art and technology. (p. 90)

This passage seems to indicate that the approach to design that is exemplified by industrial design would be the most appropriate model upon which the study of technology could be based. The implication is that industrial design synthesizes the best aspects of the analytical approach to design used by engineers with the aesthetic and emotional aspects of design used by the artist. However, using an approach that synthesizes two dissimilar approaches to design may require that technology educators have some amount of background and training in both areas to give the synthesized model its full measure. Further complicating this aspect of determining how design ought to be used to teach technology is the political implications of an alignment with the profession of engineering, the fine arts, or industrial design. Should any of these alignments come to pass each could have significant and long-term implications for technology education as a component of the general education experience of students in the public schools. The background and training of the instructors of design at technology teacher education programs across the United States will be influencing the nature of their design instruction and how the ideals of the *Standards* are interpreted. These interpretations may then affect, in both subtle and overt ways, the alignments that could occur between technology education and other professions.

The Need for the Research

The need for the study is in response to identified shortages of research in technology education. Furthermore, the study specifically addresses a need for research on design in technology teacher education. Both the purpose and the need for the research were direct responses to literature reviews and the findings from the previous stage of the research project. In addressing the need for this research, earlier work by Warner (2003) and Warner and Morford (2004) found little evidence in the literature on the “specific analysis of the status of the study of design in undergraduate technology teacher programs” (p. 35). To further emphasize the need for the present research, the work by Warner and Morford also identified several studies (Reed, 2002; Lewis, 1999; Foster, 1996; and Foster 1992) that “found declining numbers of research efforts being conducted in technology education” (p.35).

Methodology

The Conceptual Model for the Study

The goal of the present research was to identify the paradigm of the instructors of design-focused courses. A significant conceptual model for doing research with such a goal was originally conducted by Rossman in the 1930s. In 1931, Rossman, a patent attorney, completed a study to determine the common characteristics of American inventors. Rossman conducted his study by surveying over 700 active inventors, almost 200 patent attorneys, and nearly 100 directors of research and development centers. Rossman hoped that by identifying common characteristics of inventors he could provide insight into what separated them from the average man or woman and how their thinking and work habits affected both the individual inventor and those around them. Rossman's study provided a benchmark toward understanding the characteristics of inventors. Follow-up efforts to his initial study, conducted in the early 1960s, showed that the results maintained their validity (Rossman, 1964).

Limitations

As with the first year of the study, the researchers chose only to identify and then quantify the results of their investigation. The underlying goal of the entire research project was to observe and describe the contemporary status of design as a component of the process of preparing future technology education teachers. In keeping with this goal, the researchers identified and quantified the types of training, experience, and academic background indicated by the survey respondents.

Definitions of Terms

Two terms fundamental to understanding the nature and goals of this study are *paradigm* and *design-focused courses*. The first term deals with the underlying forces that influence how a college instructor interprets and interacts with design in technology. The second term deals with distinguishing what courses and course instructors were considered appropriate for inclusion in this study.

According to *The American Heritage Dictionary of the English Language* (2000) the term *paradigm* first appeared in print sometime in the 15th century. Its original meaning had to do with groupings of words that developed from a common root or stem. However, words that are in use are always in a plastic state of existence. The word *paradigm* is no exception. Kuhn's book, *The Structure of Scientific Revolutions* (1962), though still widely read in the scientific community, is perhaps best remembered for its adaptation of *paradigm*. Sallo (1999), summarized Kuhn's adaptation of *paradigm* by stating that it meant "a collection of beliefs shared by scientists, a set of agreements about how theories and problems should be understood" (¶ 13). In the succeeding years, as others have used the word to discuss their topics and issues, the meaning of *paradigm* has continued to expand. Wikipedia (2004) provides a definition that states, "in the social sciences, the term is used to describe the sets of experiences, beliefs and values that affect the way that an individual perceives reality and responds to that perception" (¶ 4). This use of the term *paradigm* fits the underlying assumption of the researchers that the perception shaping experiences of the college and university instructors teaching design-focused courses have corresponding influences on their students.

The second term to be defined is *design-focused courses*. In the earlier study by Warner and Morford (2004) the assumption was made that "most, if not all, technology education courses used or contained some component of design" (p. 37). However, the types of courses that were investigated further "were explicitly focused on design techniques or the overall design process" (p. 37). Therefore, *design-focused courses* were only those that met that filtering criteria.

Subsets of the general definition of a *design-focused course* were technique courses and synergistic courses. Once again, the earlier study by Warner and Morford (2004) defined these terms. "Specifically, technique-based courses are focused on the technical aspects of design" (p.37). The most common course titles for this subcategory included Computer Aided Drafting, Technical Drafting/Drawing, Architectural Drafting and Design, Engineering Graphics, and Graphic Communications. "Synergistic-based courses combine the technical skills with the overall thinking processes of design" (p.37). The most common course titles for this subcategory included Industrial Design, Design and Technology, Product Design, Research and Experimentation, and Design Problems/Problem Solving.

Assumptions

The researchers revisited the results of the 2002-2003 study and expanded the number of schools included in the original contact pool. The same assumptions (noted in the previous section) regarding the appropriateness of the courses included in the study from the previous year were once again applied. For this study the raw data were collected between the months of August 2003 and January 2004. It was assumed that the responses on the surveys reflected the most up-to-date information for each of the participant's career experiences.

The researchers assumed that the information provided by the department chairperson, or the designated teacher education representative, concerning who had taught the identified design-focused courses in their program was accurate and complete. Furthermore, it was also assumed that the contact information provided by each program for the identified faculty was current at the time the survey was distributed.

The final and perhaps most important assumption made by the researchers, was that the measures taken for this study were not, and could never be, a total inventory of the design paradigm shaping events experienced by each of the respondents. It was assumed that each individual had a vast array of both major and minor life experiences that played a part in shaping his or her design paradigm. Some, if not most, of those experiences have influenced the individual respondents in ways that he or she was not even aware of at a conscious level. Therefore, the events that the researchers inventoried were only those that could be clearly identified by the respondents and which could be consciously planned for, modified, or updated by any individual as the need arose.

Research Questions

The researchers came into this stage of the project with a number of questions that were an outgrowth from the 2002-2003 study. The organization of the research questions fell into two categories that were not mutually exclusive. The two categories of initial questions were (a) What was the updated status of design courses in undergraduate technology teacher education, and (b) What were the demographics and design backgrounds of the instructors of those courses? Within each of these two categories there were a number of sub-questions that were asked by the researchers. These sub-questions included:

1. How many viable technology teacher education programs exist in the United States?
2. What is the status of design courses at these programs?
3. What is the gender profile of the instructors of design-focused courses?
4. What is the formal education profile of the instructors of design-focused courses?
5. When did the instructors of design-focused courses earn their various degrees?
6. Are there any geographic patterns to the college degrees earned by the instructors of design-focused courses?
7. What were the final undergraduate majors of survey respondents when they received their bachelor's degrees?
8. What were the final undergraduate minors of survey respondents when they received their bachelor's degrees?
9. If the respondent had changed majors, what had been his or her original program of study?
10. What types of post-graduate training in technological design had the respondent received over the course of his or her career?
11. What types of industrial/private sector experiences in technological design had the respondent received over the course of his or her career?
12. What other types of design-focused experiences had the respondent received over the course of his or her career?

Data Collection

The organization and conduct of the study occurred in several phases. The first phase involved the identification of the processes and procedures, the creation of the survey instrument and its accompanying documents, and the development of an anticipated timeline. These fundamental tasks were completed by August 2003.

The second phase was the identification of programs that had not been included in the previous study. This was accomplished by an analysis of the program listings from the *2002-2003 Industrial Teacher Education Directory* (Bell, 2002). The researchers compared the list of programs from the previous study against the programs in the *Directory* that indicated they offered some type of an undergraduate technology teacher education program.

The third phase used the expanded list of programs to replicate the previous year's study and identify and quantify the design-focused courses offered in the additional programs. This involved using the Web as the primary resource for identifying each program's course offerings. Once that step had been completed and the courses had been filtered by the researchers for evaluation as having design-focused content, the department's chairperson or an identified technology teacher education representative, was contacted. This contact provided the opportunity, based on input from the identified program representative, for adjustment of both the list of programs to include in the study and the list of design-focused courses.

The fourth phase of the study involved contacting the department chairperson or the designated representative, and soliciting the contact information of the faculty members who had taught the identified design-focused courses anytime between 1999 and 2003. This contact also provided the chairperson or program representative with copies of the material to be sent to their faculty (i.e., a faculty cover letter, an informed consent document, and the survey instrument). If they chose to participate in the study they were asked to complete a design course/faculty grid sheet requesting the name, e-mail address, and office telephone number of the instructors for each of the identified courses within their program. The researchers made three attempts at contacting each of the program representatives before excluding a program from the study.

The fifth phase of the study involved contacting each of the identified instructors and soliciting their participation. The first contact was by e-mail and contained a cover letter that explained the research project, the informed consent document, and the survey instrument. If necessary, a follow-up contact was also made by e-mail. The third and final contact was made by telephone before a faculty member was excluded from the study. The questions on the survey asked the participants for information that could primarily be gleaned from their professional vitae. The questions were designed to gather both general demographic information and information about the respondent's design paradigm. The research participants were given the option of returning their completed survey instruments as e-mail attachments, facsimiles, or as printed copies through the regular mail.

The sixth and final phase of the study involved the collection, categorization, and quantification of the data. A coding system was used to provide a high degree of confidentiality about the specific answers of individual respondents. Because the goal was to examine the typical characteristics of instructors of design-focused courses, the researchers placed individual responses to each question into a database of common categories. The results were then used to create a profile of a typical instructor of design-focused courses in undergraduate technology teacher education.

The Results of the Research

Based on a thorough analysis of the listings in the *2002-2003 Industrial Teacher Education Directory* (2002), the researchers were able to ascertain that at that time there were 72 undergraduate technology teacher education programs listed for colleges and universities in the United States. The researchers compared that list against the list of 58 schools that were included in the 2002-

2003 study. The schools not in the previous study were then evaluated for design-focused courses and the department chair or the designated teacher education representative was contacted for input into the study. The results of this first stage of investigation found that four of the programs were either in the process of closing down or were essentially defunct since the program had not had a technology teacher education graduate in at least the previous five years. At this point in the study the population was 68 schools (n=68). The next process of soliciting input and participation from department chairs resulted in positive returns from 53, or 78%, of the programs.

The replication of the previous study with the inclusion of the courses from the additional programs found 312 design-focused courses at the 53 participating schools. These courses were then categorized as either technique or synergistic. The required courses numbered 103 technique-based courses and 34 synergistic-oriented courses. The researchers were able to identify 164 (n = 164) instructors of design-focused courses, both technique and synergistic based, at the 53 programs. The number of individual instructors who responded to the survey instrument was 45, or 27% of the 164 originally contacted.

The findings for the demographics of the respondents started with the issue of gender. Forty of 45 respondents, or 88% of the population, were male and five respondents, or 12%, were female.

The types of undergraduate degrees earned by the group were principally the bachelor's of science or bachelor's of science in education categories (see Figure 1). The same pattern continued in graduate school with a majority of the degrees being master's of science and master's of science in education (see Figure 2). These results should not be surprising. The technical nature of preparing someone to teach in industrial arts, industrial technology education, technology education, or any of the other permutations of this field would tend to lean toward this type of program of study. The California State University, Los Angles (n.d.) academic advisement service explains the difference as follows:

> A Bachelor's of Arts degree is humanities based degree. It is designed to provide a balanced liberal arts education and general knowledge in a recognized discipline, interdisciplinary field, or areas of professional study. A Bachelor of Science degree is science based. It is designed to provide a balanced liberal arts education and a scientific, technical, or professional entry level competence. (¶ 1)

At the doctoral level, 56%, of the respondents reported doctor of philosophy (Ph.D) degrees compared to 43% with doctor of education (Ed.D) degrees. One respondent had a doctorate of industrial technology (D.I.T.), and three others were at various stages of completing degrees (see Figure 3).

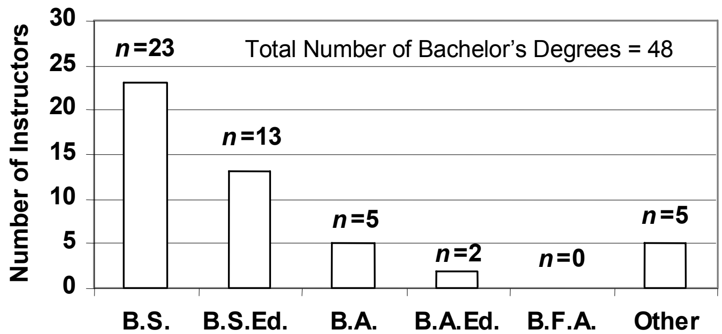

Figure 1. The number and types of bachelor's degrees identified.

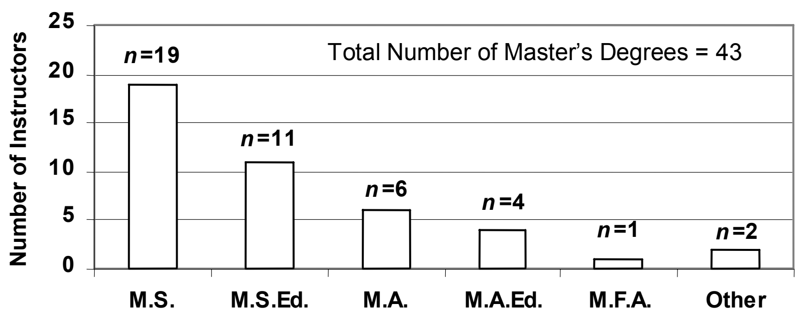

Figure 2. The number and types of master's degrees identified.

The time frame in which the respondents received their college degrees ran across nearly a forty-year spectrum during a period of dynamic change within the profession. The years that bachelor's degrees were granted ran from 1962 to 1999, with the median year being 1979 (see Figure 4). Master's degrees were granted from between 1966 and 2002, with the median year being 1985 (see Figure 5). Doctoral degrees were granted between 1971 and 2003, with the median year being 1991 (see Figure 6).

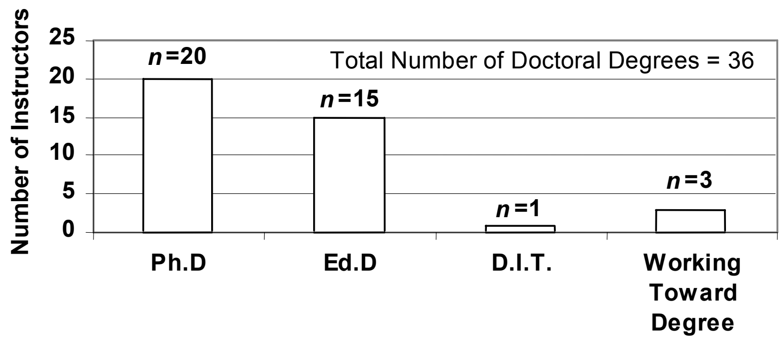

Figure 3. The number and types of doctoral degrees identified.

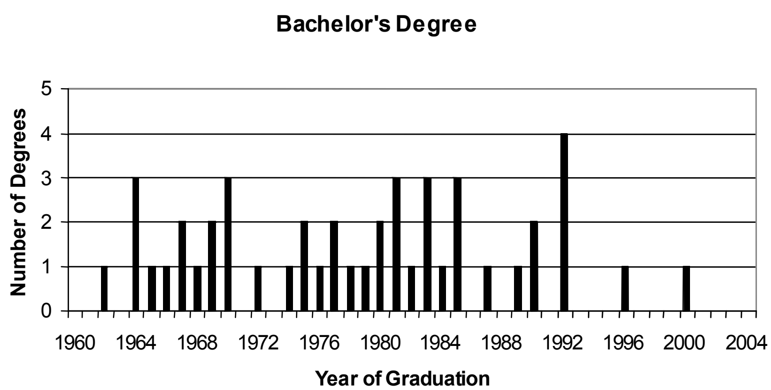

Figure 4. The year in which an instructor earned a bachelor's degree.

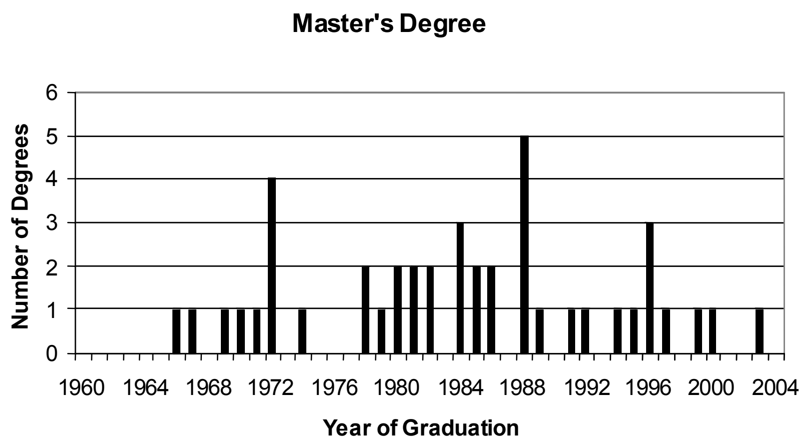

Figure 5. The year in which an instructor earned a master's degree.

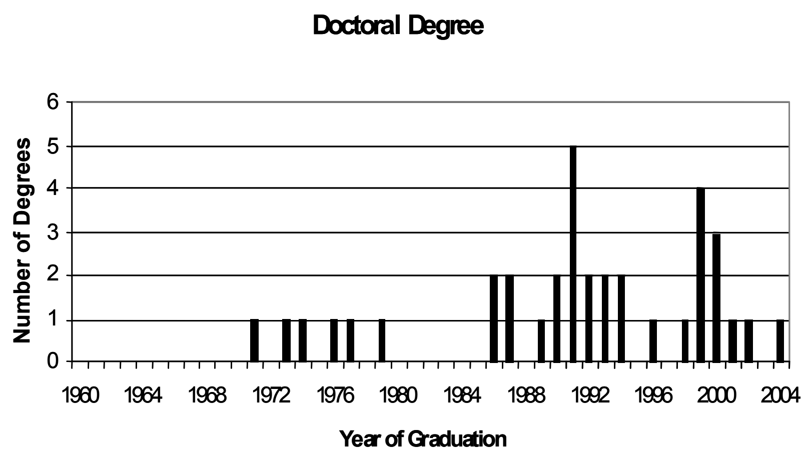

Figure 6. The year in which an instructor earned a doctoral degree.

The geographic distribution of the schools where the respondents received their various degrees is, for the most part, across the continental United States. The maps in Figures 7, 8, and 9 show the distribution of degrees granted to respondents of the survey by the state in which the granting institutions were located. With the notable exception of the western states, the geographic distribution maps indicate that the respondents received their college educations from programs across most of the country. One consequence of this type of distribution is that no one program, state, region, or agency had exclusive influence on how these respondents were educated about their content areas, including design. The noticeable lack of degrees, of any type, being granted from programs west of the Rocky Mountains, and the small number of degrees coming from any programs west of the Mississippi River, raised a number of questions. These findings may be a statistical anomaly, or they may indicate issues that are related to the distribution of industrial arts/technology teacher education programs over the last four decades, or they may indicate regional differences toward the interpretations of the content area.

Figure 7. The geography of bachelor's degrees.

Figure 8. The geography of master's degrees.

Figure 9. The geography of doctoral degrees.

The types of undergraduate majors of the respondents represent an interesting range of subject areas. As might be expected, the predominant majors were industrial arts education, industrial education, and various technology fields. However, a significant number of degrees were earned in areas such as art, the humanities, and other disciplines such as architecture (see Figure 10). It is also interesting to note that two of the bachelor's degrees were granted in technology education, perhaps indicative of representatives of the first generation of technology teacher educators who have been trained entirely under the technology education title.

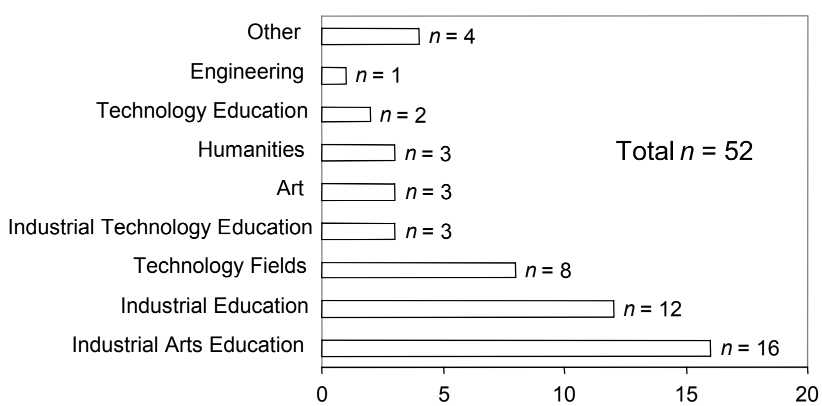

Figure 10. Undergraduate majors of survey respondents.

Table 1 provides a list of the types of undergraduate minors of the respondents. Like the variety of undergraduate majors among the respondents, this list also covers a very wide spectrum of subject areas. It is notable that only two of the categories of minors have more than one respondent. One was industrial education with two responses and the other was history, also with two responses. Just as notable was that only one respondent had a minor in design. The wide variety of minors prevented the researchers from being able to pinpoint any identifiable pattern from this particular finding.

Table 1
Undergraduate Minors of Respondents.

Art History	Mathematics
Business Education	Mechanical Engineering
Design	Packaging Technology
Electrical Engineering	Philosophy
Electronic Technology	Photography
Fine Arts	Physical Education
History (2)	Physical Science
Humanities	Physics
Industrial Education (2)	Technical Sales
Management	

A similar question on the survey asked if the respondent had been enrolled in another type of program of study before becoming an industrial arts/technology teacher education major. Just over one-quarter of the respondents had in fact changed their major at least one time when they were undergraduates. Half of those who had changed majors had been engineering students prior to entering an industrial arts/technology teacher education program (see Figure 11).

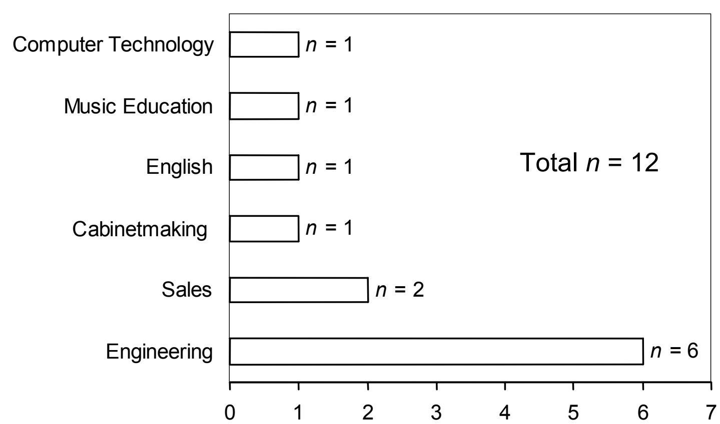

Figure 11. Former undergraduate majors for survey respondents.

Table 2
Post-Graduate Training in Technological Design

Description		**Responses**
Courses/Mini Courses/Long Format Workshops		19
Professional Development	8	
CADD	5	
Design Focused	4	
Electronics	2	
Industrial Related Training		8
Architectural/Construction/Landscaping		7
Independent Study		1
TOTAL		35

The final education related category on the survey involved the types of post-graduate training, specifically related to technological design, that the respondent had experienced over the course of his or her career. The researchers were trying to identify what types of formalized training, received after the completion of the undergraduate degree, may have shaped the design paradigm of the respondents**.** Examples included full classes that were not applied toward a degree, apprenticeships in a trade, or a summer internship. Table 2 shows the results grouped into four general categories. The most common post-graduate training for this population was through courses, mini-courses, and long-format workshops. Table 2 also shows this specific category expanded into four sub-categories. The second general category of industrial related training involved the respondents' learning technologically-based skills and knowledge on topics such as machining, model and prototype development, and specialized training for projects with the military. The third category of architectural/construction/ landscaping involved the respondents learning skills related to the design and fabrication of architectural structures and their surrounding environments. Finally, one respondent took a trip overseas to do an independent study of design in the culture, schools, and universities of Great Britain.

Table 3
Industrial/Private Sector Experiences in Technological Design

Description	**Responses**
Architecture/Construction/Landscaping	20
Trades and Crafts	11
Engineering Based Activities	11
Publications and Graphic Design	9
Invention and Product Design	5
Drafting and CADD Related Work	4
Teacher/Instructor in Another Subject Area	4
Other	5

Another question series on the survey asked about industrial/private sector experiences that the respondents may have had during their careers that focused on technological design. Examples that were provided on the survey as cues included consulting with engineers, developing an invention, working as a draftsperson, making models for an architect, designing crafts to sell at fairs, and other types of design-focused activities. Table 3 provides a list of the types and numbers of responses received for these questions.

The final category of questions asked about other types of experiences that focused on technological design. Examples that were provided included traditional seminars, workshops, and training sessions that ran from less than one day to no more than one week in length. Table 4 provides a list of the types and number of responses received for these questions. The researchers found it interesting that the most recent emphasis in this category by a significant number of respondents was on training and updating on computers and computer software. One possible interpretation for this finding is that there is an increasing use of the computer as a tool for teaching in all areas including design.

Table 4
Other Types of Design-Focused Experiences

Description		Responses
Computer Software and Hardware Training		20
Conferences/Seminars/Workshops		15
Education Related Experiences		13
Graduate Studies/Research/Teaching	9	
Curriculum/Program Development	4	
Industrial Experiences		4
Hobbies		2
TOTAL		54

Conclusions

This research provided a snapshot of the characteristics of the instructors of design-focused courses at a given point in history. Based on the responses of the participants, it can be concluded that the typical instructor for the design-focused courses offered in undergraduate technology teacher education:

- Is male
- Received his Bachelor of Science degree in 1979
- Received his Master of Science degree in 1984
- Received his doctorate in 1991
- Was likely to have earned a doctorate in philosophy (Ph.D.), if he had a doctoral degree
- Was originally trained in industrial arts education
- Has a strong background in architecture and construction

- Has attended a number of seminars/workshops/training sessions through the course of his career, most recently emphasizing updates on computer related issues.

This profile provides the answer to the basic question: what is the paradigm for the typical design faculty at technology teacher education programs across the United States? If the findings from this sampling, with its emphasis on architecture and construction, are indicative of the entire population, then it signals a paradigm disconnect from the current efforts within the profession to align with engineering. Such a paradigm disconnect among the instructors, unless addressed through professional development, will have consequences for students they serve and the profession in general. It is important to remember that the influences exerted on pre-service technology educators on how they interpret technological design will continue to have consequences for the profession at all levels of education for decades to come.

At the same time, it can be reasonably assumed that future generations of college and university instructors will have different paradigms as the ideals of the *Standards* shape and influence their understanding and use of the concepts of technological design. Toward that end, the current findings raise a number of intriguing questions. These questions include: (a) What, if any, role does the gender of the instructor play in teaching about design?, (b) How does a degree in science versus a degree in other areas such as fine arts affect the way an instructor interprets design?, (c) Does the industrial arts paradigm differ that much from the technology education paradigm when it comes to interpreting design?, (d) Why does there appear to be such a strong emphasis in architecture and construction among this group of instructors?, (e) How does this strong emphasis on architecture and construction affect the way that design is interpreted by these instructors and what are the consequences for their undergraduate students?, (f) How does the strong background emphasis on architecture and construction affect the way that other aspects of technological design, such as industrial design and engineering design, are interpreted and taught?, (g) What types of professional development opportunities, in the area of design in general and technological design in particular, are most appropriate for these instructors?, and (h) What type of design-focused content is most appropriate for inclusion in these professional development opportunities?

The answers to these questions, and the answers to other questions that will precipitate from those findings, will undoubtedly provide a clearer understanding of how design and design instruction is interpreted and how that interpretation influences the study of technology at all grade levels.

Recommendations

Identifying and quantifying this data is only the first step. Future work on this matter could take several directions. The first direction could be to replicate the study and refine the processes and procedures used to collect the data. As an example, similar research could be done using different methodologies to contact and question the department chairpersons and the instructors. The use of web-based survey instruments may be a more effective way to obtain a larger sampling of the population. Furthermore, a lack of similar research reported in the literature on this particular population means that these findings are benchmarks. Therefore, similar research could be done in the future to measure changes in the instructor profile. With the passage of time and the changing of design paradigms with successive generations of technology educators, it can be assumed that there will be some type of change in this profile.

A second direction these inquiries could take is an analysis of what these findings mean. As noted in the previous section, the current findings provide a list of questions related to the interpretation of the data. As a result, studies could be done that will try to answer each of these specific questions that deal with the analysis and interpretation of the findings from the present study.

A third direction for future research would be to explore the infrastructure that enables design to be taught in undergraduate technology teacher education programs. Examples of this type of study could include determining (a) the typical instructional strategies used to teach design-focused courses, (b) the typical instructional resources used to teach design-focused courses, and (c) the types of classroom/lab environments that best facilitate the instruction of a design-focused course.

These findings provide one more piece of knowledge toward understanding the nature of how pre-service technology educators are prepared to interpret and use design toward the study of technology. The challenge from these findings, to the profession, its individual members, and the researchers as they continue with this research agenda, is to investigate this matter further and to apply the findings toward creating opportunities for the well-rounded preparation of future technology educators.

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Miscellany

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