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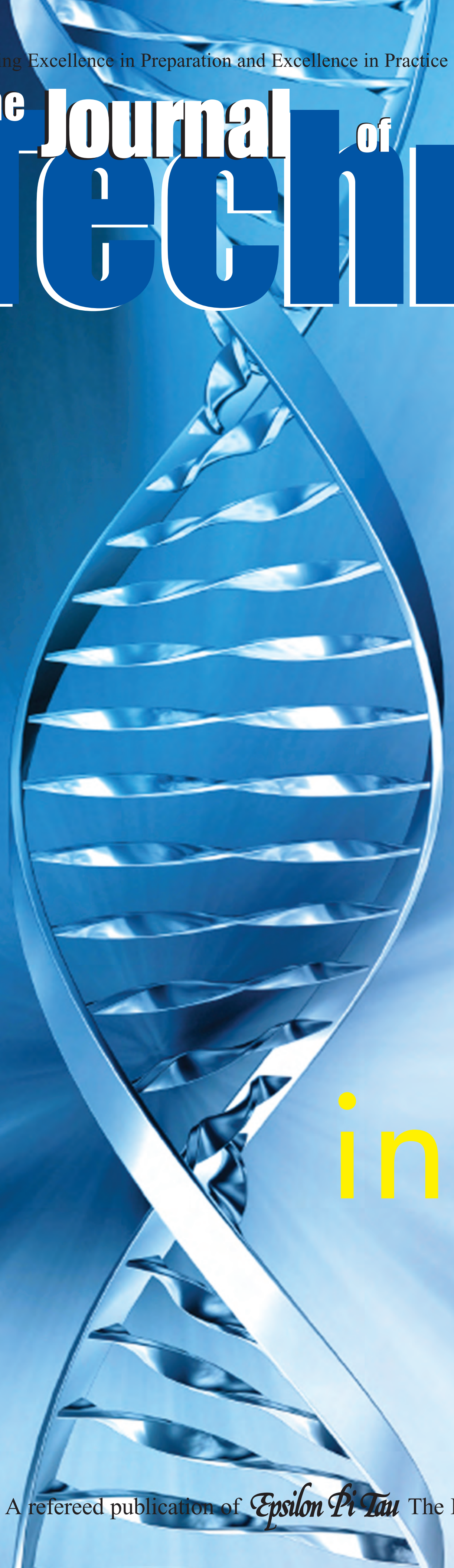

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A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

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Factors Affecting College Students' Knowledge and Opinions of Genetically Modified Foods

Chad M. Laux, Gretchen A. Mosher and Steven A. Freeman

Abstract

The use of biotechnology in food and agricultural applications has increased greatly during the past decade and is considered by many to be a controversial topic. Drawing upon a previous national study, a new survey was conducted of U.S. and international college students at a large, land-grant, Research University to determine factors that may affect opinions about genetically modified (GM) food products. Factors examined included nationality, discipline area of study, perceptions of safety, and awareness and levels of acceptance regarding GM food. Results indicated students born outside the United States had more negative opinions about genetically modified foods than did American-born students. Students who were studying a physical science-based curriculum had a more positive opinion of GM food than did students studying a curriculum that was not based in the physical science. In addition, students who reported a higher level of acceptance of genetically modified foods felt more positively about the safety of the technology.

Introduction

The use of biotechnology in food and agriculture has increased greatly during the past decade (Comstock, 2001; Knight, 2006). Global use of genetically modified (GM) plants has increased rapidly since their commercial introduction in 1996. Desirable traits (e.g., insect and herbicide resistance and improved nutritional content) have resulted in a large increase in the number of hectares planted globally. The prevalence of GM crops has increased every year since their introduction, and this will continue (James, 2008). Consumer opinions are important to the success of technological innovation in the marketplace. The purpose of this study was to examine college students' opinions in the areas of awareness, acceptance, and safety of GM foods with regard to nationality and field of study. The survey model is based upon a national survey concerning biotechnology.

Genetic modification of foods is one of many examples of the gap between scientists and nonscientists (Chappell & Hartz, 1998). Accordingly, Hoban (2001) stated that consumer awareness and understanding of biotechnology innovation has grown slowly. Despite the increased use of GM food products, GM technology is not well understood in the United States. Several recent surveys demonstrate this lack of understanding by the American public (Falk et al., 2002; Hallman & Hebden, 2005; Hallman, Hebden, Cuite, Aquino, & Lang, 2004). Although 60 to 70% of food products sold at supermarkets include ingredients using genetic modification, many consumers remain unaware of their use (Byrne, 2006). A lack of understanding among the public may lead to uncertainty about the safety of GM food products (Byrne, 2006, Hoban, 2001; Shanahan, 2003).

Consumer opinion of GM food safety also differs by nationality (Knight, 2006). Research reveals that U.S. consumers are the least concerned about GM food safety issues whereas European and Asian consumers report more concern (Chern, Rickertsen, Tsubio, & Fu, 2003; Fritz & Fischer, 2007; Pew Initiative, 2005). Even after more than a decade of debate and the increased support of governments in South America and China, the European Union and environmental groups, such as Friends of the Earth, continue to reject the cultivation and use of genetically modified crops (Weise, 2010).

College students form a subpopulation of the general public and an area of interest concerning GM food opinions. Within the United States, college students may mingle among nationalities, a previously cited factor of perceptions concerning GM food safety. College students are likely to be younger and more highly educated than the general population and may have a greater awareness of agriculture biotechnology (Finke & Kim, 2003). Science-based coursework, laboratory work, and the beliefs of professors and instructors may contribute to awareness, and these beliefs may be reinforced within the student's major area of study. As young adults, students may not have formed a strong opinion about this subject, and they may be more open to the different perspectives of agriculture biotechnology (Wingenbach, Rutherford, & Dunsford 2003).

College graduates are more likely to be more open-minded, and they have been shown to have lower prejudice levels and increased knowledge of global issues (Rowley & Hurtado, 2002). Concerning GM food products, college students in the United States show a lack of understanding about the concepts and processes behind GM technology. Wingenbach, et al. (2003) found that even though college students surveyed felt confident in their knowledge of biotechnology practices, only 30% answered the questions correctly. A weak relationship was found between the students' perceived and actual knowledge of biotechnology and between students' assessed knowledge and level of acceptance for biotechnology practices (Wingenbach, et al., 2003).

Nationality has been found to be a significant factor in college student opinion concerning GM foods, just as it has been with the general population (Gaskell, 2000; Hallman & Hebden, 2005; O'Fallon, Gursoy, & Swanger, 2007). In a study of Korean and American students, approximately 42% of U.S. students expressed concern about health risks from GM food and over 86% of Korean students felt the same level of concern (Finke & Kim, 2003). Only 14% of Korean students surveyed felt no concern compared with 42% of U.S. students who perceived no concern about the health risks of consuming GM foods.

When compared with previous research, this study is based on a wider demographic of students and included all students enrolled at a Midwestern land-grant research-intensive institution. Additionally, the international students participating in this study were students at an American university. In previous studies, the students were enrolled at universities in their home countries (Finke & Kim, 2003; Li., Curtiss, McCluskey, & Wahl, 2002). Unlike previous research, students from all disciplines were included versus students in specific disciplines (Finke & Kim, 2003; Wingenbach et al., 2003). All of these differences have the potential to affect students' knowledge and opinions.

Methodology

To measure awareness, acceptance, and safety perceptions, a previously validated instrument was utilized (Hoban, 2001). Four-scaled response items were used to determine respondent awareness, usage acceptance levels, and safety perception regarding GM foods. When measuring awareness, four-point scales were used ranging from "none" to "a lot." To determine the awareness of the students, two questionnaire items were used. The first asked the students how much they had heard about genetically modified food products, and the second item asked if they had consumed a product containing GM foods. This methodology was employed because past research has indicated that very few Americans surveyed know the extent of GM ingredients contained within foods sold in the United States. Several studies have found very low numbers of Americans surveyed have been able to correctly answer survey questions about consumption of GM foods. In this case, the assumption was that students who knew a lot about GM foods would also recognize that they had most likely consumed GM products (Falk et al., 2002; Hallman & Hebden, 2005; Hallman et al., 2004; Pew Initiative, 2003).

The relationship between awareness and acceptance was also explored. One theory of awareness and acceptance is that the more people know about a biotechnology, the more intense their support or opposition will be for this topic (Fischoff, 1995). An additional outcome of increased awareness is an emotional response that the GM foods were "hidden" from them without their consent (Hoban, 2001). The third item on the survey was used to explore the relationship between the variables of awareness (both perceived and actual) and safety perception.

The final item on the survey queried students on their support of the use of genetic modification in food and agriculture areas. This item measured the students' acceptance of GM technology as applied to food and agriculture, and it was tested against field of study, nationality, and awareness levels to determine if a significant relationship existed. The relationship between acceptance levels and safety perceptions of students was also tested.

Three additional questions asked students about their nationality and field of study. Students indicated their field of study on the questionnaire and were also asked to identify the academic unit where their major was administered. Researchers classified the majors as either physical science based or non-physical science based. The instrument is shown in Figure 1.

Physical science is defined by the *Merriam-Webster Dictionary* (2009) as fields in which the

1. How much have you heard about genetically modified food products?
   a. A lot b. Some c. Little d. Nothing
2. Have you consumed genetically modified food products?
   a. Yes b. No c. Not sure
3. How safe are genetically modified food products?
   a. Safe b. Unsafe c. Not sure
4. Do you support the use of genetic modification in agriculture and food?
   a. Yes b. No c. Not sure
5. To what College does your academic discipline belong?
   a. Agriculture b. Business c. Design
   d. Engineering e. Human Sciences f. Liberal Arts & Sciences
6. What is your major?
7. What is your nationality?
   a. American-born b. Born internationally

Figure 1. Questions from the data collection instrument.

properties of energy and nonliving materials are studied. Although physical science is strictly defined by fields such as physics, chemistry, astronomy, and geology, some overlap with fields in the biological sciences is often apparent. These fields might include biochemistry, biophysics, virology, and paleontology. In the case of this study, physical science fields included disciplines such as agricultural biochemistry, food science, and meteorology, in addition to the subject areas listed in the definition.

The instrument was pilot tested on a small subgroup of the target population (n = 26). The seven-item survey was administered electronically to the student body attending an upper Midwestern land-grant research-intensive university. A cover letter preceded the survey to brief subjects about the project and its purpose. Consent of respondents was assumed if the student voluntarily clicked on the link to begin the survey. Because participation was voluntary, a delimitation of the study was the self-selection of the student sample. Data collection was guided by three research questions:

1. Do college students have an accurate awareness of their knowledge of GM food technology?
2. Do nationality, field of study, or acceptance levels affect college students' perceptions of safety concerning GM foods?
3. Does college students' level of acceptance for GM foods vary by nationality or field of study?

Using SPSS, version 14, frequency distributions were performed on demographic characteristics (field of study, nationality, and academic college of enrollment) and cross-tabulations were carried out for awareness and consumption patterns. To test whether a relationship existed between variables the Chi-square test of independence was used (Agresti & Finlay, 1999, pp. 261-262). On selected variables, adjusted residuals were studied to learn more about the nature and strength of the relationship identified by the Chi-square test of independence (Agresti & Finlay, 1999).

Results

Valid questionnaires were received from 762 students. The responses were representative of the total campus population regarding field of study and nationality (Iowa State University Office of Institutional Research, 2005). Table 1 shows the characteristics of the students surveyed. Uneven sample sizes are the result of missing data.

Table 1. Characteristics of Student Sample

Nationality[1]	Frequency	Percentage
American	718	94.3
International	43	5.7
Major [2]		
Physical Science	361	47.6
Non-Physical Science	344	45.4
Unsure 53	7.0	
Academic Unit of Major[3]		
Agriculture	191	25.9
Business77	10.4	
Design 39	5.3	
Engineering	188	25.4
Human Sciences	214	29.0
Liberal Arts & Sciences	30	4.1

[1]N = 761; [2]N = 758; [3]N = 739

Frequency data for the question on awareness of GM foods are presented in Table 2. The results illustrate a student body relatively confident in its knowledge of GM foods, with nearly 75% of the students stating they had either some or a lot of knowledge. Less than 4% of students surveyed had heard nothing about genetic modification of foods.

Table 2. Student Awareness Levels Concerning GM Foods

Awareness Level	Frequency	Percentage
Heard Nothing	29	3.8
Heard a Little	170	22.3
Heard Some	349	45.8
Heard a Lot	214	28.1

[1]N = 762

Awareness and consumption were compared in Table 3 to answer the first research question asking if college students have an accurate perception of their knowledge of GM food technology. Students were queried about both awareness levels and consumption patterns to see if these variables aligned. These data suggest that awareness and consumption do align: students who had more awareness were more likely to believe they had consumed GM foods. Students who had less awareness were more likely to be uncertain about their consumption patterns.

Table 3. Cross-Tabulation of Perceived Awareness and Consumption of GM Food Products

Consumption[1]	No	Not Sure	Yes	Percentage
Awareness[1]				
Nothing	0	26	3	3.8
A Little	3	130	37	22.3
Some	5	146	198	45.8
A Lot	4	22	188	28.1
Percentage	1.6	42.5	55.9	100

[1]N = 762

The Chi-square test of independence was used to test the associations of safety perceptions with field of study, nationality, and level of acceptance. Level of acceptance was tested for associations with field of study and nationality. Table 4 illustrates the associations found among survey variables using the Chi-Square test of independence. Four of the five variable pairs tested showed evidence of a dependent relationship.

Adjusted residual analysis was used to determine the nature and relative strength of the relationships identified as dependent (Agresti & Finlay, 1999, pp. 261-262). The difference between the observed frequency of a specific variable pair and its expected frequency creates a value called the residual. A positive residual occurs when the observed frequency is greater than the expected frequency needed to predict an independent relationship, and a negative residual occurs when the observed frequency is smaller than the expected frequency needed to predict an independent relationship between the two variables (Agresti & Finlay, 1999, pp. 261-262).

An adjusted residual value above 2 provides evidence against the null hypotheses of an independent relationship between each pair of variables and adjusted residual values above 3 are considered strong evidence for a significant relationship between the two variables (Agresti & Finlay 1999, pp. 261-262). Table 5 illustrates the pairs of associations and their standardized adjusted residuals.

The pairs of variables exhibiting evidence of an association or a strong association are identified in Table 5. The adjusted residual values greater than 2 suggest students who study in physical science-based majors are more likely to feel positively about the safety of GM foods than those who study in fields outside the physical science areas. Additionally, American students were found to feel more positively about the safety of GM foods than did international students, as measured by the adjusted residual values greater than 2. Finally, adjusted residual values provide evidence that college students who study in physical science-based majors are less likely to be uncertain regarding their

Table 4. Chi-Square Values and Significant Levels of Variable Pairs

Variables	Chi-Square Value	Degrees of Freedom	Significance Level
Safety Perceptions / Field of Study[1]	9.96	4	0.041*
Safety Perceptions / Nationality[2]	9.80	2	0.007*
Safety Perceptions / Level of Acceptance[1]	419.90	6	0.000*
Level of Acceptance / Field of Study[3]	9.78	4	0.044*
Level of Acceptance / Nationality[2]	1.68	3	0.641

[1]*n* = 758; [2]*n* = 761; [3]*n* = 762; *Significant at _ = .05

Table 5. Residual Values of Relationships with Safety

Levels of Safety Perceptions	Field of Study		
	Physical Science		Non-physical science
Safe[1]	2.7*		-2.2*
Unsafe[1]	0.8		-0.7
Unsure[1]	-3.1**		2.5*
	Nationality		
	American-born		Internationally-born
Safe[2]	2.6*		-2.6*
Unsafe[2]	-2.3*		2.3*
Unsure[2]	-1.6		1.6
	Acceptance Levels		
	Yes	No	Unsure
Safe[3]	14.6**	-9.4**	-9.6**
Unsafe[3]	-8.4**	15.1**	-2.1*
Unsure[3]	-11.3**	3.1**	10.7**

[1]*n* = 705; [2]*n* = 761; [3]*n* = 762; *evidence of association; ** evidence of strong association

Table 6. Residual Values of Relationships Between Acceptance Variable Pairs

Levels of Acceptance	Field of Study	
	Physical Science	Non-physical Science
Yes[1]	1.7	-1.7
No[1]	1.3	-0.7
Unsure[1]	-2.9*	2.5*
	Nationality	
	American-born	Internationally-born
Yes[2]	-0.2	0.2
No[2]	-1.0	1.0
Unsure[2]	1.0	-1.0

[1]*n* = 705; [2]*n* = 760; *evidence of association; ** evidence of strong association

support of GM food products than are college students studying in non-physical science areas.

The strongest relationships in the safety perceptions group are with levels of acceptance. These data suggest those who are more supportive of GM foods are more likely to feel these foods are safe, and people who do not support GM food products are less likely to think the foods are safe, as shown by the high positive residual values for high acceptance and perceptions of safety. High negative values for negative and uncertain acceptance levels with a positive perception of safety illustrate a strong negative relationship between the factors of acceptance levels and perceptions of safety.

Discussion and Implications of Research

The survey sample was drawn from the student body at an upper Midwestern land-grant university. Students from all academic areas of the university were represented. The results suggest students have an accurate understanding of their knowledge of GM food as represented by awareness and consumption. Students who believed they had greater awareness also believed (correctly) that they had consumed GM food. Of those who believed they had at least a little knowledge of genetic modification in foods, over 94% thought they had consumed GM foods, whereas less than 4% of students who professed at least a little knowledge of GM foods believed they had not eaten the foods.

Assuming knowledge of consumption also represents awareness, the low numbers of respondents who professed a lot of knowledge, but no consumption may also be individuals who pay very close attention to what they eat rather than consumers who have overestimated their knowledge. Avoiding GM foods requires a great deal of effort and an unusually advanced knowledge of the food and agriculture system (Hallman & Hebden, 2005; Pew Initiative, 2003; Wingenbach et al., 2003). However, it must be acknowledged that although it is difficult to not consume foods made with GM products in the United States, it is not impossible.

Finally, the strongest relationship found among variables was between acceptance and safety: students who were unsure about their acceptance of GM foods were also more likely to feel uncertain about the safety of the products. This finding is clearly illustrated by the strength of the evidence provided by the standardized adjusted residuals for an association between the variables of acceptance and safety. If strong evidence for association is provided by residuals of 3 or greater, the extremely high positive residuals between high levels of acceptance and high safety perceptions (residual value = 14.6) highlights a very strong relationship between the two. Those who had high levels of acceptance also showed a strong negative association with high uncertainty (residual value = -11.3) and low safety perceptions (residual value = -8.3).

The same relationship patterns were apparent with low levels of acceptance and uncertain acceptance. Those who had low acceptance levels also believed that GM foods were unsafe (residual value = 15.4). Students who were uncertain concerning their acceptance of GM foods were more likely to also feel uncertain about the safety of GM food products (residual value = 10.6). Accordingly, those who were uncertain about their acceptance of GM foods were also less likely to have high perceptions of safety (residual value = -9.7).

Nationality appears to play a role in the safety perceptions of college students, because American students felt more positively about GM technology as used in food and agriculture and international students felt more negatively about it. However, student nationality and acceptance levels were unrelated, contradicting previous findings (Finke & Kim, 2003).

Field of study was a relevant factor: physical science students were less likely to be uncertain about both safety perceptions and levels of acceptance. Physical science students felt more positively about safety (residual value = 2.7) than non-physical science students (residual value = -2.2), and this aligns with a previous study (Priest, 2000). This is a more novel area of study with regard to biotechnology: relatively few studies include how field of study affects a student's opinion of biotechnology.

The relationship between academic discipline of the students and their perceptions of safety and acceptance illustrates the continuing divide between scientists and nonscientists on topics considered controversial (Chappell & Hartz 1998; Priest 2000). Priest (2000) found people who have a broad university-level science education are more likely to feel more positively about the use of genetic modification in foods; this study found that physical science students felt more positively about the safety of GM foods and were less likely to be uncertain in their acceptance of the technology than were students who were not studying in a physical science discipline.

Although students of physical science have been shown to have stronger positive safety perceptions and likely to be more certain regarding their acceptance of GM technology in this study, these findings have broader implications for scientific communication. It is often the nonscientist who does the communicating, in the form of marketing, writing, or education on scientific topics such as genetic modification of foods. Students in areas other than physical science were found to be less certain in their acceptance of GM foods and less confident in the safety of these foods. Increased scientific and technical training for the nonscientist on controversial science topics (such as genetic modification of foods) could address some of these knowledge gaps.

There were also several delimitations to the study. The population chosen for this study was drawn from a single university, and it may not be representative of U.S. college students in general. The students self-selected when responding to the survey. Those who elected to take part in the study may have perceptions, knowledge, and opinions quite different from those who did not participate. Uneven and small group sizes among international students prevented researchers from dividing this group further. Some students provided unclear descriptions of majors, and these were classified as unknown and were not included in the Chi-square tests of independence. All of these factors may limit the ability to generalize the results of this study.

Future research in this area is recommended, especially in the area of academic discipline with additional factors of acceptance and safety perceptions. Similar research among multiple universities would improve the ability to generalize results to a wider population. Students are an important section of the general population; they also represent the next generation of leaders helping to shape public opinion about biotechnology, and, in general, technology awareness, and adoption. Thus, understanding students' knowledge of and opinion on the topic of biotechnology use in foods is important to both the scientific community and the nonscientific community.

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Technology Education to Engineering: A Good Move?

P. John Williams

Abstract

Recent curriculum changes in the educational system of Australia have resulted in allowing optional Engineering course work to count for university entrance for students choosing to apply to a university. In other educational systems, Engineering is playing an increasingly important role, either as a stand-alone subject or as part of an integrated approach to Science, Mathematics, and Technology. These developments raise questions about the relationship between Engineering and Technology education, some of which are explored in this article.

Introduction

Curriculum agendas that include a proposed link between Technology and other curriculum areas rarely seem to favor Technology. When Science and Technology are offered in primary schools, science is prioritized, and consequently technology is not delivered well (Williams, 2001). This is a function of both primary school facilities and primary teacher training. Science and Technology offerings in secondary schools tend to be quite academic rather than practical (Williams, 1996). Numerous Science, Technology, and Mathematics (STM, SMT, or TSM) projects that have been developed around the world produce interestingly integrated curriculum ideas and projects, but these have rarely translated into embedded state or national curriculum approaches. This is partly because the school and curriculum emphasis on Science, Technology, and Mathematics is not equivalent across these areas. Even the earliest integrated approaches involving these subjects promoted reform in Science and Mathematics (LaPorte & Sanders, 1993) rather than the goals of Technology. Recently, Engineering, has been brought into the mix as a number of Science, Technology, Engineering and Math (STEM) projects have been developed, most significantly, in terms of numbers and influence, both in the United Kingdom and the United States. Again, the agenda for this type of amalgamation is not being driven by a desire to progress the goals of technology education; rather, it is being driven by a desire to improve Science and Mathematics education in order to increase the flow of STEM people into the workforce and to improve STEM literacy in the population (Barlex, 2008). Despite the idea that Mathematics and Science education can be improved by combining them with Engineering and Technology this has not been proved, and the concept of STEM literacy is a bit befuddling and ill defined.

Much has been written about the synergistic relationships among Science, Mathematics, and Technology, particularly between Science and Technology. A succinct summary of these relationships has been provided by Kimbell and Perry (1991):

> Science provides explanations of how the world works, mathematics gives us numbers and procedures through which to explore it, and languages enable us to communicate within it. But uniquely, design & technology empowers us to change the made world. (p. 3)

Allied with the STEM approach is a Technology education revisionary movement toward adding Engineering in schools, particularly in U.S. schools. Technology educators who promote this approach do so out of the frustration that has come from the absence of general recognition of Technology education after many years of advocacy, and they propose it as an adjustment to the focus of Technology education (Gattie & Wicklein, 2007). The fact that William Wulf, the President of the National Academy of Engineering wrote the foreword for the "Standards for Technological Literacy" (International Technology Education Association, 2000) is heralded as a significant benediction (Lewis, 2005) to the shift from Technology education to Engineering (Rogers, 2006). The rationales are various and dubious, but they are similar to those presented for the STEM agenda:

- Increase interest, improve competence, and demonstrate the usefulness of mathematics and science (Gattie & Wicklein, 2007).

- Improve technological literacy (Rogers, 2005), which promotes economic advancement (Douglas, Iversen, & Kalyandurg, 2004).

- Provide a career pathway to an engineering profession (Dearing & Daugherty, 2004; Wicklein, 2006).
- Improve the quality of student learning experiences (Rogers, 2006).
- Give preparation for university engineering courses (Project Lead the Way, 2005).
- Elevate technology education to a higher academic and technological level (Wicklein, 2006).

Although there has been considerable discussion on this topic, there seems to be very little discussion about the similarities, differences, and the relationship between Technology and Engineering as school subjects. STEM is a confused acronym in which Engineering has a different type of relationship to Technology than Science does to Mathematics. This is because Engineering is actually a subset of the broad area of Technology. For example, the Science equivalent would be to link Science, Biology, and Mathematics. While some apologists have developed rationales for the consideration of Technology as a discipline (Dugger, 1988), it actually is interdisciplinary, and it relates to Engineering, along with a range of other disciplines in both the sciences and the arts.

Because of the aforementioned suspicion of any alliances between Technology and other subjects, this author's intent at the beginning of this article was to search Engineering and Technology curricula and other literature, determine the differences, and make consequent conclusions. However, after researching this topic, it became evident that this would not be a simple task. Thus, the primary focus of this article is to determine if the main areas of deviation between Engineering education and Technology education exist in the nature of the process and the definition of relevant knowledge.

Process

Contrasted with an historical focus on Engineering knowledge, the nature of the Engineering process has received more attention (Malpas, 2000). The procedural terminology for Engineering education is generally the same as that used in Technology education – for example, formulating a problem, generating alternatives, and analyzing and evaluating (Eggert, 2005). Eggert (2005) elaborated that in Engineering,

> whether we are designing a component, product, system or process, we gather and process significant amounts of information . . . We try to determine desirable levels of performance and establish evaluation criteria with which we can compare the merits of alternative designs. We consider the technical, economic, safety, social or regulatory constraints that may restrict our choices. We use our creative abilities to synthesize alternative designs . . . (p. 2).

Both the language and the sentiment of this description of Engineering design would be familiar to Technology education teachers. Although there are many descriptions of the Engineering process, just as there are many explanations of the Technology process, the general and superficial judgment is that there are no significant differences.

With the promotion of Engineering as a focus for Technology education, an analysis of the nature of the Engineering process should be added. The depth of this analysis varies from "engineering design is the same as technological design" (International Technology Education Association, 2000, p. 99) to the idea that the Engineering design process centers around the four representations of semantic, graphical, analytical, and physical (Ullman, 2003). In his summary of design in Engineering, Lewis (2005) pointed out this remains an area of contention, with "some in the engineering community believing that design lacks the definitive content and rigor [that typifies engineering], while others contend that creativity cannot be taught" (p. 45), and other tensions within Engineering center on the questionable value of hands-on learning that accompanies design.

Lewis (2005) quoted Peterson's (1990) qualification that design is not a science and has no rigorous rules for progression. This presents problems for more traditional Engineering educators who see the Engineering process as predictable and quasi-scientific. In contrast, Cross (2000) perceived that the design process, while variable and evolving, tends to become formalized. To further indicate the diversity of approaches to Engineering design, the Cambridge Engineering Design Centre is developing evolutionary computer-based methods to optimize conflicting design criteria in a diverse range of areas, such as improving hybrid electric vehicle drive systems, trading-off reduction in pollutants and noise in aero-engines, and designing cheaper and more compact space satellites (Cambridge Engineering Design Centre, 2009).

Gattie and Wicklein (2007) concluded that the fundamental difference between the design processes in Engineering and Technology is the absence of mathematical rigor and analysis in technology that precludes the development of predictive results and consequent repeatability. This reflects Lewis's (2005) earlier discussion that if Technology educators are to embrace Engineering, one implication is that more Science and Mathematics would need to be taught to students, so that they could approach the devising of design solutions from a more analytic framework, thus enabling them to have predictability about the design outcome prior to its production.

This thinking has led a number of authors to divide design into conceptual design and analytic design, the former being common in Technology education and the latter a part of Engineering. Analytic design may be utilized to ensure functionality and endurance, and it involves static and dynamic loads and consequent stresses and deflections. Thermodynamic analyses may be required in order to make yield and fatigue judgments.

Conceptual design is less predictive. Success in Technology education is determined by what "works," which is initially defined by a range of criteria, and through a process of research and idea development, a solution is first produced and then judgments are made about its success. In Technology education, it is not possible to predict what will work with certainty because of the diverse qualitative variables involved. It is a process of experimentation and modelling that leads to a solution. In Engineering, experimentation and modelling lead to the verification of a solution, prior to its development. This is obviously essential, given the nature of engineering projects.

This difference may be illustrated by a model bridge-making exercise, which is a common project in both Engineering and Technology education. In Technology education, after students develop an understanding of design factors, they will then construct a model bridge and test it to destruction. They will analyze the model and the testing process to further develop their understanding. They possibly will construct another model as a result of the information they have discovered. In Engineering, students will develop an understanding of the design factors, and then analyze all the variables to ensure that the model will conform to the design requirements. Next, they will construct the model. If the testing of the bridge indicates that it does not meet specifications, the design has failed.

Thus for engineers, the design criteria are more deterministic, implying that a more limited range of outcomes are possible and there is less opportunity for divergent and creative ideas to develop. For technologists, the design criteria are more open, permitting a broader range of acceptable outcomes.

Herein lies a key difference between Engineering design and Technology education. "The most notable difference in the design process is that engineering design uses analysis and optimization for the mathematical prediction of design solutions" (Kelley, 2008, p. 51). The use of Science and Mathematics to develop a body of knowledge that enables the analysis and testing of prototype solutions prior to their production is a feature of Engineering. This does not mean that Engineering design is necessarily more informed (McCade, 2006), it is just a different type of design that requires more prerequisite knowledge and is less divergent in outcome possibilities.

Petroski (1996) characterized this difference as the importance of failure considerations, such as "the ability to formulate and carry out the detailed calculations of forces and deflections, concentrations and flows, voltages and currents, that are required to test a proposed design on paper with regard to failure criteria" (p. 89). This prediction of failure, while still present in Technology education activities, is less pervasive and not as crucial.

A discussion of this difference should take place in a context of general or pre-vocational education. Engineering as a school subject that has a pre-engineering or a vocational goal, which is the framework for most of the cited discussion, will necessarily employ a design process that is aligned with the nature of Engineering design: one that is more analytic and based on a defined body of knowledge. However, some authors and curriculum development projects promote Engineering design in lower secondary and even primary schools, which at this level should not be vocational but general. A design process at lower levels of education that prioritizes analytic design and is preceded by the mastery of a body of knowledge and consequently limits creativity and divergent thinking is inappropriate. Projects such as "Primary Engineer" are in fact engaging in Design and Technology and presumably use the Engineering label for reasons related to status or recognition.

Technology Education in Western Australia

Prior to the application of this discussion to a specific context, an introduction to the Technology education curriculum in Western Australia follows. In this area, in 2000, a state curriculum framework was introduced that included eight learning areas, one of which was Technology. These learning areas were developed and used in schools as a trial for implementation in 2005. The "Technology Learning Area Framework" was a radical departure from previous curricula in the area, which were content specific in a quite detailed way and focused on teacher inputs. The new framework was outcomes based and specified content in a general way. It brought together a number of previously discrete subjects that included a similar process focus and philosophical basis. The subjects were Home Economics, Design and Technology, Computing, Agriculture, and Business Studies.

The kindergarten to year 10 Technology curriculum is defined in terms of outcomes and content. The seven outcomes are:

1. TECHNOLOGY PROCESS. Students apply a technology process to create or modify products, processes, systems, services, or environments to meet human needs and realize opportunities.

2. MATERIALS. Students select and use materials that are appropriate to achieving solutions to technology challenges.

3. INFORMATION. Students design, adapt, use, and present information that is appropriate to achieving solutions to technology challenges.

4. SYSTEMS. Students design, adapt, and use systems that are appropriate to achieving solutions to technology challenges

5. ENTERPRISE. Students pursue and realize opportunities through the development of innovative strategies designed to meet human needs.

6. TECHNOLOGY SKILLS. Students apply organizational, operational, and manipulative skills appropriate to using, developing, and adapting technologies.

7. TECHNOLOGY IN SOCIETY. Students understand how cultural beliefs, values, abilities, and ethical positions are interconnected in the development and use of technology and enterprise.

Table 1 gives an idea of the relationship between outcomes and content. The content has been developed into a scope and sequence, but it is quite broad and open to interpretation.

During the 2000-2005 period of progressive implementation of the Framework, it became clear that it did not encompass the last two years of secondary school. In these years, students at school did one of the following: prepared for university entrance, began preparatory vocational studies for later transfer to a tertiary vocational institution, or studied school designed and assessed subjects. In 2001, the government reviewed the upper secondary curriculum (Curriculum Council, 2001). Among the recommendations of the review were to replace the existing 270 subjects available to students with 50 courses of study, each of which would have the same preparatory status for either university entrance or vocational studies. The courses were to be outcomes based and consistent with the previously devised and implemented Learning Area Framework.

This was a particularly positive outcome for the Technology Learning Area Framework, which up until this time did not offer students courses that could be used for university entrance; the focus was on vocational preparation for other post-school destinations. Of the 50 proposed courses, those that represent a continuation of Technology studies in the lower secondary years are listed in Table 2.

The significance of the change for Technology education is obvious in the number of technology-related study options that are now available to students, compared with the former situation in which they had none. Students can

Table 1. Design and Technology Outcomes and Content.

Technology Process
• Investigating
  • Processes
  • Features, properties and use
• Devising
  • Generating and communicating designs
  • Conventions and considerations
• Producing
  • Techniques
  • Considerations
• Evaluating
  • Outputs
  • Methods
	Systems
	• The nature of systems
	  • Form and attributes
	  • Context and impact
	• The use and development of systems
	  • Investigating
	  • Devising
	  • Producing
	  • Evaluating

Materials
• The nature of materials
  • Form and attributes
  • Context and impact
• The selection and use of materials
  • Investigating
  • Devising
  • Producing
  • Evaluating
	Enterprise
	• Enterprising attitudes
	  • Maximising opportunities
	• Enterprising capabilities and skills
	  • Generating ideas
	  • Communicating and managing
	  • Evaluating outputs
	  • Evaluating methods

Information
• The nature of information
  • Form and attributes
  • Context and impact
• The creation of information
  • Investigating
  • Devising
  • Producing
  • Evaluating
	Technology Skills
	• Organizational skills
	  • Materials
	  • Information
	  • Systems
	• Operational skills and manipulative skills
	  • Materials
	  • Information
	  • Systems
	Technology in Society
	• Influencing factors
	• Consequences
	  • Process – investigating
	  • Materials
	  • Information
	  • Systems

Note. Adapted from "Engineering Studies" by Curriculum Council, 2008, Perth: Curriculum Council.

Table 2. Technology-Related Courses Years 11-12.

Accounting and Finance
Agriculture (Animal or Plant)
Applied Information Technology
Automotive Engineering and Technology
Aviation
Business Management and Enterprise
Career and Enterprise Pathways
Construction
Design
Engineering Studies
Food Science and Technology
Materials, Design, and Technology
Media Production and Analysis

select from these subjects and use their achievement as the basis for further university or vocational studies. These new courses have been and are being progressively implemented in schools from 2006 through 2011.

Technology is taught as general education to grade 10, and then a range of more specific subjects are available for students in grades 11-12. In this curriculum, the technology process is elaborated according to these two stages: lower secondary and upper secondary. The curriculum is different at these two stages: lower secondary is a part of the K-10 general education curriculum, and upper secondary includes the type of subjects listed in Table 2 (pre-vocational education). Some elements of the technology process are listed in Table 3, and they indicate the difference between these stages.

In support of the previous literature review, it is clear that the process takes on a different focus when students progress beyond general Technology education into a more specific technological area such as Engineering. The curriculum becomes more analytical, more explicitly related to Mathematics and Science, and more focussed on industry and commercial standards.

Table 3. Aspects of the Technology Process.

TECHNOLOGY PROCESS	
Lower Secondary (Yr 8-10)	**Upper Secondary (Yr 11-12)**
Key design features and properties of technologies can determine functionality and suitability to use	Mathematical and scientific analytical methods applicable when examining the functionality and suitability for use of particular technologies
Strategies for generating designs and plans that meet specified standards and criteria (e.g., how to find appropriate standards and criteria)	Ways to plan and design solutions to technology challenges that incorporate analysis of detailed factors of production (e.g., choices of materials, techniques and costs, people needed)
Functional, aesthetic, social, and environmental issues to be addressed when devising solutions to technology challenges	Mathematical and scientific principles appropriate for use in developing plans and proposals
How to meet detailed specifications and standards when developing products, systems, services, and environments	How to meet detailed specifications and market/commercial standards when developing products, systems, services, and environments
Methods of organizing and maintaining a variety of tools, resources, and equipment	Industry-standard risk management strategies
Predetermined, detailed specifications and standards that can be used to evaluate personal work	Commercial specifications and standards of quality, presentation, and performance for evaluating technology products

The different approaches to design taken by Engineering and Technology indicate that Technology education is more appropriate as a component of general education.

Knowledge

The initial hypothesis of this discussion was that the scope of Technology is broader than that of Engineering. If it were accepted that Engineering is a subset of Technology, and there are many Technology areas that are not Engineering (architecture, industrial design, biotechnology, computing), this would seem to be a plausible hypothesis. Therefore, if Technology education deals with the breadth of Technology, then Engineering as a subject would be more limited. Given that one of the virtues of Technology is that teachers can choose to teach aspects that are of interest to them and relevant to their students, it would seem that limiting this scope would be a disadvantage.

However, the scope of Engineering in some contexts is presented as very broad. In his book on Engineering Design, Eggert (2005, p. 16) refers to the following roles of engineers in the product realization process: sales engineer, applications engineer, field service engineer, industrial engineer, design engineer, materials engineer, industrial engineer, manufacturing engineer, quality control engineer and project engineer. In an educational context, the New South Wales Engineering Studies Syllabus (Board of Studies, 2009) lists the following areas of Engineering as those from which study modules will be developed: aerospace, aeronautical, agricultural, automotive, bioengineering, chemical, civil/structural, electrical/electronic, environmental, marine, manufacturing, materials, mechanical, “mechatronic,” mining, nuclear, and telecommunications. This author’s hypothesis that the definition of the knowledge that accompanies Engineering and Technology will be different, with the former both more limited and more defined than the latter, would not seem to be as plausible as originally thought. Although this list of Engineering fields is broad, a defined body of knowledge exists for each area, which becomes a discrete curriculum unit.

Engineering knowledge is proposed by some to be taught prior to the application of that knowledge, because it can be defined, and then it can inform the design process. “The idea is that design is informed, as opposed to being the result of a guess or multiple guesses” (McCade, 2006, p. 73). For example, the New York State Center for Advanced Technology Education proposed the development of prerequisite skills and knowledge before the design process is utilized (McCade, 2006). Petroski (1998), however, noted that design should be taught to students early in their Engineering education, which would enable them to achieve significant procedural understanding.

A similar debate exists among technology educators. Some propose that students should master a range of manipulative skills and materials understandings before they proceed to engaging in design, so that their design work can be informed, reasonable, and possible (e.g., Merrill, Custer, Daugherty, Westrick, & Zeng, 2008). The alternative proposition is that in this approach design thinking would be constrained by the skill and material understandings that students possess, which would consequently limit creativity and innovation, so the skills involved in learning how to design should be taught and practiced at the same time as manipulative skills and the study of materials (Johnsey, 1995; Pavlova & Pitt, 2000). A pedagogical argument is invoked in support of this latter approach, which states that skills and knowledge are more effectively learned if they are taught at the time of need. In this case, need generated through problem solving because this allows students to immediately apply the skills and knowledge they have obtained in response to their felt need.

This latter approach, of concurrent experiences in the development of procedural and content knowledge, highlights the question of what knowledge is relevant in the study of both Engineering and Technology. If a particular content area of Engineering is being taught, such as civil or automotive, then there is a defined and acceptable body of knowledge related to that area which forms the parameters for the development of design projects. However, this is not the case with Technology where there is no defined body of knowledge, so the question arises: What knowledge is relevant?

The answer to this question highlights the difference between Engineering and Technology. In Technology education, the relevance of technological knowledge to a problem or design brief is defined by the nature of the problem. The information that is needed to progress the solution of a technological problem becomes the body of relevant knowledge, which of course cannot be defined prior to analyzing the problem. This also specifies the accompanying pedagogy in that content cannot be taught in the absence of a design problem. The design problem is analyzed, possible pathways to a solution are projected, and the pursuit of the solution determines the knowledge that is relevant.

In Engineering studies, the context, which defines the relevant body of knowledge, is predetermined, be it chemical, marine, automotive, and so forth. Because the content determines relevant knowledge and is not dependent on the nature of the design problem, the task for the student is different in Engineering than Technology.

In the light of this discussion it is useful to examine some of the Engineering curriculum. As explained previously, in a number of Australian states, students study Design and Technology to the tenth grade; they then have the option of progressing to study Engineering in grades 11 and 12. A brief description of the nature of these Engineering studies is as follows:

During the course Engineering studies in Western Australia, “students will explore how the design of structures, machines, products and systems have become increasingly sophisticated over time to improve our quality of life. They will develop an insight into how engineering has influenced all aspects of our lives by impacting on cultures, societies and environments. The course provides challenging, practical ways and opportunities for students with different interests to design and make things by applying engineering principles to solve problems and meet particular needs or market opportunities” (Curriculum Council, 2001, p. 1).

The course was originally conceived as design focussed, broadly covering a range of Engineering-related areas of study in a practical way. However, during its development, some more conservative university Engineering educators became involved, and the course has evolved into a quite limited approach to Engineering. Despite the statement that the “course content is sufficiently diverse to provide students with the necessary foundation to meet employment needs in a range of occupations not limited to the engineering industry” (Curriculum Council, 2008, p. 3), there is a core plus three specialist fields that provide options for study:

CORE:	Engineering design and process enterprise, environment and community
SPECIALIZATION:	Mechanical engineering, or electronic/electrical engineering, or systems and control.

Therefore, even though this includes some general aspects, the focus is quite vocational.

In New South Wales, the subject Engineering Studies “develops knowledge and understanding of the profession of engineering”

(Board of Studies, 2009, p. 6), but this includes quite a broad focus, with the following rationale:

> No longer do engineers only formulate problems, provide solutions and integrate technical understanding. Key responsibilities for the profession now include responsible wealth creation, taking full responsibility of ethical considerations and the aim of sustainability in meeting the needs of society. With such key responsibilities, engineers now place increased importance on areas such as communication, synthesis and analysis of information, management skills and teamwork. (p. 6)

The breadth of approach in this course is further illustrated by the modules from which it is constructed – these are in the areas of household appliances, landscape products, braking systems, bio-engineering, civil structures, personal and public transport, lifting devices, aeronautical engineering, and telecommunications engineering. The study of all these modules is compulsory for each student.

In the state of Queensland, the title of the subject that is available to secondary students, Engineering Technology (Queensland Studies Authority, 2004), muddies the waters of this discussion further. It does not mention preparation for the engineering profession, it does however say that this subject should benefit all students by developing their technological literacy through the provision of real-life problem-solving activities in a wide range of student interest areas. Students must study four (or more) of the following areas: energy technology, environmental technology, manufacturing technology, communication technology, construction technology, and transportation technology.

In general, it seems that even though the rationale for studying Engineering in the final years of secondary schooling has a pre-vocational focus, it also has a more general focus that may apply to students who are interested in broad technical areas rather than specific preparation for studying Engineering at a university. Universities that specify high school Engineering as a prerequisite for entering Engineering courses tend to emphasize the vocational aspect of the school subject.

Conclusion

The process and the knowledge related to Technology education and Engineering studies are different; Technology education is more appropriately a component of general education, and Engineering studies are more vocational. The implication in terms of the school curriculum is that Technology education is a component of primary and lower secondary education, and Engineering is part of the upper secondary schooling. This position is summarized in Table 4:

Table 4. Lower and Upper Secondary Technology Studies.

Schooling	**Up to year 10**	**Years 11-12**
Subject	Design and Technology	Engineering
Focus	General	Vocational
Process	Designerly	Analytic, Math/Sc dependent
Knowledge	Defined by the problem	Defined by the context

The process of Engineering design involves problem factor analysis, which is dependent on an understanding of applicable Science and Mathematics. This is not a significant aspect of the type of design carried out in Technology education. It provides less scope for the achievement of the general goals related to creativity and lateral thinking because it is more constrained.

The knowledge needed to solve a Technology education problem is ill defined until the nature of the problem is fully explored and the design process is underway. The knowledge needed to solve an Engineering problem is predefined by the type of engineering that is being studied, so there is less scope for the student to explore and consequently define relevant knowledge.

Technology education is a more appropriate curricula vehicle for the achievement of general technological skills than is Engineering, but a system of education where Engineering studies at upper secondary school follows a general based Technology education at the lower secondary level would be a logical progression, and a "good" move for Technology education.

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Improving Geometric and Trigonometric Knowledge and Skill for High School Mathematics Teachers: A Professional Development Partnership

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Abstract

In the summer of 2009, a professional development partnership was established between the Peoria Public School District (PPSD), a local education agency (LEA), and Illinois State University (ISU) to improve geometric and trigonometric knowledge and skill for high school mathematics teachers as part of the Illinois Mathematics and Science Partnership (MSP) grant, which was funded by the Federal Department of Education. The MSP is aimed at improving the content knowledge of mathematics teachers regarding the implementation of three-dimensional (3-D) solid modeling in the mathematics classroom; the ultimate goal is to improve students' learning in mathematics. The premise for this professional development grant can be found in the literature that suggests that there is a significant positive relationship between spatial visualization abilities and mathematical performance. Also, the literature implies that spatial ability and visual imagery play vital roles in mathematical thinking. Further, the professional development program maintains that spatial visualization and reasoning are core skills that all students should develop. Eight mathematics teachers from the PPSD and the LEA's Mathematics Coordinator completed over 80 hours of professional development geared toward the improvement of teaching mathematics; they used 3-D solid modeling software (SolidWorks, 2009) during the summer and fall semesters of 2009 and during the spring 2010 semester, these teachers conducted action research projects based on their professional development. Formative and summative evaluation techniques were developed and implemented.

Introduction

In the summer of 2009, a professional development partnership was established between the Peoria Public School District (PPSD) and Illinois State University (ISU) to improve geometric and trigonometric knowledge and skill for mathematics teachers as part of the Illinois Mathematics and Science Partnership (MSP) grant, which was funded by the Federal Department of Education. The purpose of this MSP grant was to improve the content knowledge of mathematics teachers (seven high schools and one middle school) regarding the use and implementation of three-dimensional (3-D) solid modeling in the mathematics classroom. The ultimate goal is to improve student learning in mathematics. The premise of this professional development can be found in the literature that suggests that there is a significant positive relationship between spatial visualization abilities and mathematical performance. Additionally, the literature implies that spatial ability and visual imagery play vital roles in mathematical thinking. Further, the professional development program maintains that spatial visualization and reasoning are core skills that all students should develop. Therefore, the purposes of this research are to (a) share related literature on spatial visualization as it pertains to mathematics, (b) highlight a collaborative professional development program for mathematics teachers that utilized a 3-D solid modeling software approach to better teach geometric and trigonometric concepts, (c) explain the initial findings of this professional development program, and (d) discuss implications for collaborative efforts among science, technology, engineering, and mathematics (STEM) educators.

Eight mathematics teachers from the PPSD and the LEA's Mathematics Coordinator completed more than 80 hours of professional development geared toward the improvement of teaching mathematics using 3-D solid modeling software during the summer and fall semesters of 2009 and the spring 2010 semester. These teachers conducted action research projects based on their professional development. Formative and summative evaluation techniques have been developed and implemented to measure the affect of this professional development experience.

At the conclusion of the spring 2010 semester, eight new mathematics teachers from PPSD were selected to participate in the second part of this professional development program, and they were matched with four of the original eight cohort members. The four original mathematics teachers will serve as mentors and teacher leaders for the new group. The research team has planned to scale up the cohort for a third-year professional development program, in which members of the first and second groups, aligned with select science teachers from PPSD, will complete an integrated 3-D program. This professional development program has been funded for a total of $283,948 for the 2009 and 2010 fiscal years.

Background of Proposal and Requirements

The broad goal of the Federal MSP program is to increase the academic achievement of students in mathematics and science by enhancing the content knowledge and teaching skills of classroom teachers. More specifically, according to the request for proposal (RFP), the goals for the MSP programs follow: (a) to improve teacher's subject matter knowledge, strengthen the quality of mathematics and science instruction, and promote student academic achievement in mathematics and science; (b) to promote strong teaching skills through access to the expertise of mathematicians, scientists, and engineers and their technologies and resources, including integrating reliable scientifically based research teaching methods and technologically based teaching methods into curriculum; and (c) to increase the understanding and application of scientifically based educational research appropriate to mathematics and science teaching and learning. Specifically, the research plan, directed by external evaluators and dovetailed with the Federal MSP guidelines, was to examine (a) teacher change in terms of content and pedagogical content knowledge; (b) quality of professional development activities; (c) teacher perceptions of their current preparedness; (d) teacher attitudes toward teaching; (e) frequency of using designated instructional resources; (f) teacher use of promoted practices, including inquiry-based lessons and implementation of 3-D visualization tools in the classroom; (g) design, implementation, content, and culture of the professional development experience; (h) student change by analyzing state and district test scores, as well as any additional criterion-referenced student assessment; and (i) collaborative efforts between and among the mathematics teachers.

The RFP required a partnership between an institution of higher education and a high-need school district. In the RFP, a high-need district was defined as one in which 50% or more of their students were failing to meet the state's learning standards, as evidenced by performance on state achievement tests. The district also must have a student population of which 15% or more of the students who are from low-income families, and the district must be facing teacher quality issues, including inappropriate certification or teaching assignments. The partnerships were viewed in the RFP as a way to bring the resources of an institution of higher education (equipment, space, libraries, etc.) to a high-need school. The higher education faculty involved in this professional development program were from the College of Applied Science & Technology and the College of Education. Each member of the higher education faculty had an interest in science, technology, engineering, and mathematics (STEM) teaching and learning, but none had a formal degree in science or mathematics.

The RFP specified that there must be a summer workshop-style program for professional development that consisted of 80 hours or more of professional development with at least four follow-up days during the following academic year. The workshop was to be designed to utilize state-of-the-art technologies used by scientists, mathematicians, and engineers and to encourage there use in the classroom. The intended participants were to be mathematics and science teachers with less than 10 years of experience who had leadership potential. After completion of the scheduled professional development, the teacher participants would be expected to complete an action research project to determine the effectiveness of their learning. The intended outcomes of the professional development were clearly an increase in teacher content knowledge, instructional practice, and an improvement of student academic achievement in mathematics.

After careful examination of the goals of the MSP's RFP, the research team contacted the Mathematics Coordinator at PPSD. The rationale for partnering with PPSD includes its geographical relationship to ISU, successful past experiences regarding educational initiatives, and the research team's efficacy toward partnering with a school district that is dynamic, yet poses myriad challenges.

PPSD has a 30.5% White student population (state average 54%), 61.1% Black student population (state average 19.2%), and a 5.5% Hispanic population (state average 19.9%). The low-income rate for PPSD is 70.3% (state average 41.1%). The mobility rate of students (families) in PPSD is 30.1%, which is more than double (14.1%) the state average. The total student enrollment for PPSD is 13,642. The number of economically disadvantaged students taking the mathematics exams totaled 5,182 (13,642 total students in PPSD), whereas the number of disadvantaged students taking the science exam was 2,034 (Illinois District Report Card, 2008). The PPSD did not earn adequate yearly progress in 2008. The graduation rate of PPSD students was 75% (Illinois District Report Card, 2008).

Student achievement is lacking in the LEA. The American College Testing (ACT) assessment score for the graduating class of 2008 in PPSD was a composite 18.7 score. In mathematics, PPSD students earned an 18.8 (state average 20.6), and in science, PPSD students earned an 18.4 (state average 20.3). The percentage of students who met or exceeded the standards on the 2008 state achievement exam in mathematics and science were 37.3 and 31.9; both scores fell well below state averages. This level of failure is systemic throughout the school district. The percentage of students in sixth, seventh, eighth, and eleventh grades who did not meet the minimum level of achievement in mathematics was 32.9%, 29.7%, 29.6%, and 44.7%, respectively. The percentage of seventh and eleventh grade students who did not meet the minimum level of achievement in science was 18.6% and 53.3%, respectively (Illinois District Report Card, 2008).

When the research team conducted a needs assessment with the LEA mathematics teachers and LEA Mathematics Coordinator, the following themes emerged as the areas of most need/interest:

- Increasing teachers' understanding and application of research to improve student learning (research must be teacher and school friendly);
- Promotion of strong teaching skills (e.g., effective instructional strategies);
- Improved subject matter knowledge (both teachers and students);
- Access, use, and implementation of technology in the classroom to promote new and improved teaching skills and student knowledge/skill; and
- Inquiry-based (problem-based) teaching and learning.

Based on the findings of the needs assessment and discussions with the LEA Mathematics Coordinator, the research team devised a cutting-edge professional development program, based on literature findings and grounded in the premise of helping students to learn and improve their mathematical ability. It also provided mathematics teachers with the opportunities to improve their pedagogical approaches in the classroom. Based on the findings of the needs assessment, the research team explored related literature centered on mathematics, 3-D solid modeling, and the connection with teacher content knowledge, pedagogy, and assessment.

Related Literature on Mathematics and 3-D Solid Modeling

The National Council of Teachers of Mathematics in its 1989 *Curriculum and Evaluation Standards for School Mathematics* came forward with an attempt to "create a coherent vision of what it means to be mathematically literate" (p. 67). The NCTM has since revised its standards (NCTM, 2000), seeking to simplify and clarify its vision with the *Principles and Standards for School Mathematics (PSSM)*. The standards made explicit that technology should be used in teaching, stating that, "appropriate calculators should be available to all students at all times" (p. 8), and previously it stated:

> Technology, including calculators, computers, and videos, should be used when appropriate. These devices and formats free students from tedious computations and allow them to concentrate on problem solving and other important content. They also give them new means to explore content. As paper-and-pencil computation becomes less important, the skills and understanding required to make proficient use of calculators and computers become more important. (NCTM, 1989, p. 67)

Recommendations at the high school level also called for the use of technology. The integration of ideas from algebra and geometry is particularly strong, with graphical representation playing an important connecting role. The standards also called for increased use of computer-based explorations of 2-D and 3-D figures and real-world applications and modeling as well as decreased attention to paper-and-pencil graphing of equations by point plotting and paper-and-pencil solutions to trigonometric equations (NCTM, 1989). Instructional technologies for the mathematics classroom were being developed and refined. The most dominant is the graphing calculator.

Although mathematics researchers and educators clearly acknowledge the role of technology in mathematics instruction, research findings in mathematics education also suggest there is a significant positive relationship between spatial visualization abilities and mathematical performance, and that spatial ability and visual imagery play vital roles in mathematical thinking. Seng and Chan (2000), for example, stated “much of the thinking in higher mathematics is spatial in nature” (p. 2). Furthermore, “positive correlations have been found between spatial ability and mathematics performance at all grade levels in solving problems that involve geometry” (Seng & Chan 2000, p. 2). Jones & Fujita (2002) claimed that students cannot solve geometrical problems unless they can create proper geometrical images in the mind. Similarly, the National Council of Teachers of Mathematics (NCTM) contends that 2-D and 3-D spatial visualization and reasoning are core skills that all students should develop (Christou et al., 2007).

Because spatial ability has been shown to correlate to mathematics performance, there are obvious concerns for students who have less-developed spatial skills. In many studies, for example, females have been shown to possess fewer visualization skills than their male counterparts (Medina, Gerson, & Sorby, 1998; Melancon, 2001; Sorby, 1999). In a 2008 study, Moore and Johnson found that males tended to perform better than females on spatial relationships/visualization. Researchers do not know why males surpass females at spatial visualization, but note that the differences can be found in as early as five months of age (Moore & Johnson, 2008); four and one-half years of age in a 1999 study by Levine, Huttenlocher, Taylor, and Langrock. Levine et al. (1999) also noted that spatial visualization gaps between genders widen as both genders mature in age. In a 2007 meta-analysis study on gender differences in spatial abilities, McNulty found that researchers have only been able to indicate that a gender difference exists in mentally manipulating objects. Linn and Peterson (1985) found male subjects favored mental rotations, whereas Alexander (2005) found that females favored visual memory. McNulty synthesized from a study conducted by Ginn and Pickens (2005), that “women who participated in music, art, or athletics had more experience with spatial activities than women who did not participate in these activities” (p. 17). Although instruction in mathematics relies heavily on graphical images to convey conceptual ideas, the current mathematics curriculum offers little formal support to foster the acquisition of spatial skills. This is unfortunate, because neglecting instruction in spatial competence could discriminate against the less spatially minded student.

Dynamic Geometry Software (DGS) has been used in the mathematics classroom since the late 1980s to help teach the principles of geometry (Christou et al., 2007). Even though most of the DGS applications that are available to mathematics teachers are 2-D in nature, a handful of 3-D DGS systems are being developed and tested (e.g., Kaufmann, Steinbügl, Dünser, & Glück, 2008). The mathematics research community is excited about the development of the new 3-D DGS applications because these provide opportunities for students to create and explore geometric shapes that are rendered and easy to visualize. “Computer software for the teaching of 3-D geometry should allow students to see a solid represented in several possible ways on the screen and to transform it, helping them to acquire and develop abilities of visualization in the context of 3-D geometry” (Christou et al., 2007, p. 3). Although 3-D geometry construction is relatively new and still under development in the DGS field, 3-D solid modeling is a mature technology that has been the mainstay of the engineering community for decades.

The engineering community has been using computer-aided design (CAD) software since the 1960s. Early 2-dimensional CAD systems were used to create product designs using curves, such as lines, arcs, and splines. As time progressed, 3-D CAD systems were developed that allowed the definition of 3-D objects. Early 3-D CAD systems common in the 1970s and 1980s used surface modeling technology to describe the outer envelope of products. Though surface modeling was a significant improvement over 2-D modeling, the lack of interior product details limited the use of this CAD data. Today, almost every 3-D CAD system used in mechanical design utilizes solid modeling technology. Solid modelers unambiguously define the entire 3-D object, which allows the CAD data to be used in new ways. For example, specific materials, such as metals or plastics, can be applied to a solid model making it possible to evaluate many physical properties of the design, such as weight, center of gravity, and strength.

One of the most significant trends in engineering graphics in recent years has been the maturation and widespread adoption of constraint-based solid modeling technology. A significant advantage of constraint-based modelers is the ability to define 3-D solid models using a series of modifiable features. In a constraint-based modeler, the modeling process usually starts by creating a 2-dimensional sketch, which is then "swept" to create a 3-D solid. The 2-D sketches are comprised of coplanar curves, such as lines and arcs, which have been geometrically and dimensionally constrained. Geometric sketch constraints are geometric rules that describe how the sketch should behave when edited. For example, two lines can be constrained to always be perpendicular, two circles can be constrained to always share the same center point (concentric), and a circle can be constrained to be tangent to a line. In addition to geometric constraints, specific dimensions are added to sketch geometry to further constrain the sketch. A line, for example, may be constrained using an explicit numeric dimensional value, such as 2 inches, or a mathematical expression, such as "line length = 2/3 circle diameter." The use of constraints is critically important because they allow the sketches to behave predictably during editing. The ability of constraint-based solid modelers to create modifiable "dynamic" models rather than static solid models offers great advantages to industry (Bertoline & Wiebe, 2007).

Because many of the principles of geometry are used when creating models using 3-D constraint-based solid modelers, and 3-D solid models are displayed in a rendered form that is easy to visualize, it is reasonable to assume that using a 3-D solid modeler during mathematics instruction could benefit some learners. Even though there is agreement that 3-D solid modelers share many aspects of the new 3-D DGS applications, some researchers contend that 3-D CAD systems are not well suited for geometry education. Kaufmann et al. (2008), for example, argued that commercial CAD software is too complex and the learning curve too steep for use in the mathematics classroom. There are, however, several published studies in which constraint-based solid modelers have been used in the K-12 classroom to teach in a variety of STEM-related disciplines, including mathematics, physics, and engineering technology.

Devine (2008) conducted a study to measure the extent to which using a constraint-based solid modeler during high school mathematics instruction affects student learning. Devine's study used two intact groups, a control group and an experimental group, to measure the extent to which using a parametric solid modeler during instruction affects student learning relating to the mathematical principles of areas and volumes of solids. The control group was taught using traditional instructional methods, and the experimental group was taught using a combination of traditional methods and experimental methods utilizing a constraint-based solid modeler. At various times during each class period, the researcher worked through problems for the students using a solid modeler. The computer images were projected on a screen for all students to see. The solid modeling techniques used typically involved creating and constraining a two-dimensional sketch, which was then extruded or revolved to create a solid. Named expressions were used to dimensionally constrain the sketches, with the expression names chosen to match the mathematics terminology presented in geometry texts. Boolean operations provided opportunities to illustrate the concept of volumetric addition and subtraction. The solids were shaded, rotated, and sometimes sectioned to help the students visualize the shape. When specific information was required for a calculation (e.g., height and diameter of a cylinder), the dimensions were obtained both algebraically and graphically using various measuring functions in the software.

In Devine's (2008) study, the students who received instruction using the solid modeler scored 3% higher on their unit exam. The cooperating mathematics instructors were also quick to point out that they observed many nonquantifiable benefits to using the software during geometry instruction. The instructors commented that the rendering capabilities of the system allowed students to visualize the geometry like they had never before experienced in their classes. One female student, for example, excitedly told her instructor that for the first time all year she had been able to visualize the geometry concepts being taught in the class. The mathematics instructors also commented that the solid modeling software allowed them to test their students' understanding of geometry principles by asking probing questions they would not normally be able to answer using graphical means (Devine, 2008).

Planchard (2007) described a project in which educators in a variety of STEM fields used a commercially available constraint-based solid modeling application called SolidWorks. The overarching objective of the project was to improve the understanding of STEM principles through the use of 3-D CAD software. Additionally, the project was designed to enhance instructors' skills in instructional design by utilizing 3-D CAD to illustrate theory. Planchard's (2007) project also provided a venue to share resources for STEM-related courses. The project provided SolidWorks software to teachers, from middle school to college level, who represented a wide range of STEM disciplines. The instructors developed lesson plans that required students to use SolidWorks in some manner. Secondary instructors developed lessons for Algebra, Art, Biology, Calculus, Chemistry, Geometry, Robotics, Technology, and Trigonometry. All lesson plans were posted on a web blog sponsored by SolidWorks for other instructors to see and use. Even though many of the instructors involved in Planchard's project did not have any prior experience of working with 3-D CAD software, they were able to learn SolidWorks with little difficulty. Planchard stated, "for both instructors and students, 3-D CAD software provides a powerful complement that makes science, technology, engineering, and math more understandable" (2007, p. 4).

Traditionally, instruction in many STEM disciplines has been deductive in design, beginning with abstract theories and progressing to applications of those theories. Alternatively, inductive instructional methods start with specific observations, case studies, or problems, and theories are taught or students discover them only after the need to know them has been established. Inductive methods are constructivist in nature and require students to take more responsibility for their learning. Inductive methods have been shown to be at least as effective, and in most cases more effective, than deductive methods (Prince & Feldner, 2006). A review of the SolidWorks education blog (http://blogs.solidworks.com/teacher) revealed that many instructors used SolidWorks as a vehicle to employ inductive methods in many disciplines. One instructor, for example, created a lesson to allow students to examine trigonometric ratios on circles of varying radii, thereby discovering that the ratios remain constant regardless of the radius of the circle. Another lesson helped students to discover the formula to figure the sum of the interior angles of an *n*-gon.

The use of commercially available 3-D CAD software to teach STEM principles has many potential benefits. The ability of constraint-based solid modelers to provide feedback to learners that is both immediate and readily observable is an ideal tool to promote inductive learning in many STEM disciplines. Furthermore, because a 3-D solid modeler is the tool of choice for engineers and technologists in the workplace today, exposure to this modern technology may demonstrate how mathematics principles are used in the real world. This is important because educational researchers have long realized the importance of context in the learning environment, and the lack of an authentic context for learning experiences has long been a concern in mathematics education (Hiebert & Lefevre, 1986; Silver, 1986). Exposure to real- world applications of mathematics and science also may help students to see value in pursuing STEM-related education (Kesidou & Koppal, 2004; Raju, Sankar, & Cook, 2004; Swift & Watkins, 2004).

Discussion of SolidWorks as a Tool for Mathematics

SolidWorks was selected for use in this project because it is one of the most popular constraint-based solid modelers available today, and it has technical capabilities that rank among the leaders in the industry. Another benefit to this project was that SolidWorks is widely used in K-12 schools and supporting materials, including numerous text-books and a SolidWorks teachers' blog, are readily available. Finally, SolidWorks is currently being used in other grants, such as the NSF-funded "Biomechanics and Robotics Explorations for IT Literacy and Skills in Rural Schools," which is underway at East Carolina University. Because granting agencies encourage grant recipients to disseminate grant materials and lessons learned, the use of SolidWorks also had nontechnical benefits.

The general approach taken in this project was to work with the participants (middle and high school teachers) initially to help them learn the basic functionality and real-world applications of the SolidWorks application. However, prior to the discussion of how SolidWorks was used as a tool in mathematics classrooms it is worth listing what each teacher participant received for being a part of this professional development program. As mentioned previously, the PPSD is extremely poor, and therefore many items that other school districts may take for granted are not an option for purchase. Each teacher participant from PPSD and the PPSD Mathematics Coordinator were given a laptop computer, an LCD projector, a security lock, a backpack, a 3-D mouse, a stipend to attend professional conferences, advanced SolidWorks training outside of the normal professional development program, 3-D manipulative cubes for the classroom, an individual and district-wide site license for SolidWorks, a financial stipend for being part of the professional development, over $850 worth of educational textbook and reference materials, screen capture software, a laptop camera and microphone, and six hours of graduate credit. In addition, the LEA received a financial allocation for administrative costs.

The use of SolidWorks as an educational tool in mathematics began through teacher professional development sessions. The professional development sessions started with a focus on the basic functionality of SolidWorks. During each weekly meeting, the participants observed software demonstrations and completed hands-on activities using their laptop computers loaded with SolidWorks software. Early sessions were somewhat prescriptive in nature, with participants completing exercises that were assigned by one of the principle investigators. Participants completed "homework" assignments, including software tutorials, between sessions.

Specific attention was paid initially to the basic concepts of creating planar (2-D) sketches comprised of lines and arcs, which are then swept using either the extrude or revolve operations to create 3-D geometry. While working in the 2-D sketcher environment, specific mathematical relationships (constraints) were applied to the curve geometry. These rules included basic mathematical concepts, such as parallelism, perpendicularity, concentricity, and more. The participants used SolidWorks to create curves, apply the designed geometric rules, and "drag" the geometry on the screen to see the resulting behavior of the geometry. While working with the 2-D geometry, geometric properties, such as perimeter and surface area, were also explored.

Because the strength of any solid modeler lies in the 3-D capabilities of the software, and the fact that there are other 2-D software tools available for use in the mathematics classroom, the next logical step was the transition from 2-D to 3-D geometry. Basic sweeping operations such as extrude and revolve were explored at length. Using the extrude function, previously created 2-D sketches were swept linearly a specified distance along a vector, thus creating 3-D solid geometry. The geometry could then easily be rendered and rotated to help the user visualize the 3-D shape. The 2-D sketches were also revolved to form 3-D solids. When using the revolve function, the 2-D sketch is rotated about a linear axis to create a 3-D solid.

As the professional development sessions progressed, the sessions became less prescriptive and more varied based on input from the participants. The participants were frequently asked to comment on how the software functions that they were learning might be helpful in the mathematics classroom. The teachers were also asked to identify specific "problem" areas where they thought the use of SolidWorks might be helpful. As a group, the participants and principle investigators brainstormed to identify other software tools and possible demonstrations and/or activities that would help improve mathematics instruction. Of interest to the teachers was the ability to visualize the results of revolving the same set of 2-D curves about different axes. The concepts of Boolean operations (unite, subtract, and intersect) and 3-D geometric properties such as volume and center of gravity could now also be explored.

After the participants had explored and grown comfortable with the basic functionality of SolidWorks, some advanced functions were targeted that had specific mathematical applications of interest to the teachers. For example, the ability to create 2-D curves using mathematical functions and the ability to link various model dimensions using mathematical equations and an Excel spreadsheet were explored. Finally the ability to convert a 3-D solid into a 2-D "net" using the sheet metal design function of SolidWorks was explored.

Over time, the professional development sessions shifted away from weekly demonstrations and modeling "assignments" toward explicitly exploring ways that SolidWorks could be used during mathematics instruction to improve student learning. Each participant was asked to develop a detailed lesson plan in which they would use SolidWorks in some way to help teach mathematics. This transition dovetailed well with the increased professional development emphasis placed on teaching pedagogy and action research.

In addition to the SolidWorks and mathematics education professional development listed above, teacher-based and school-based issues were discussed, knowing that mathematics is only one area associated within the larger circle of the school. For example, during the last 15 hours of the fall 2009 professional development program, educational materials, such as *How Students Learn: Mathematics in the Classroom* (National Research Council, 2006), *Qualities of Effective Teaching* (Stronge, 2007), *The Art and Science of Teaching* (Marzano, 2007), and *Classroom Strategies for Helping At-Risk Students* (Snow, 2005), were discussed in order to bridge the use of SolidWorks with best practices in teaching and learning. The concluding piece of professional development is a focus on action research in which the focus of inquiry is to determine the affect that their new knowledge of SolidWorks had on their students and instruction.

Mid-Program Findings

Described in this section is an abbreviated synthesis of the evaluation results from the mid-year professional development evaluation conducted by the external evaluators. The external evaluators found that the teacher participants rated the *quality* of the professional development experience as a 4.4/5.0. Teacher participants commented that this professional development experience had provided them with the opportunity to reflect on their practice with fellow teachers and share ideas for improvement. Teacher participants rated the *value* of the professional development experience as a 4.5/5.0, despite feeling that their students would not likely have the ability to understand 3-D visualizations. When asked whether the teacher participants would recommend this professional development experience to other teachers, all teacher participants said "yes," yielding a 5.0/5.0. The "impact of the professional development program on teachers' understanding of how to use technology in their classrooms" was rated as a 4.1/5.0, despite very positive written comments provided by the teacher participants. When asked about the "impact of the professional development program on teachers' understanding of integrated STEM", the teacher participants yielded a mean score of 4.0/5.0. Teacher participants noted that being able to integrate STEM activities in their classrooms seems to be segregated due to the nature of the school/district setting. "The extent to which teachers' instructional practice has improved as a result of the professional development program" yielded a 4.2/5.0 mean score.

Barriers and Lessons Learned

During the time this professional development initiative had taken place and as the research team moves forward into the next phase, the LEA school board voted to close one of its four high schools, all teachers without tenure were given a "pink slip," the current year's teaching contract went to a "vote to strike" before being ratified, and the superintendent decided to retire mid-year. Any one of these events would be enough to cause severe chaos for the teachers in this LEA, but despite these events, the teacher participants continued their professional endeavors, even knowing that they will likely be without a teaching position the next school year. Needless to say, the research team has learned a great deal about professional development with an LEA that is facing adversity at many different levels. Although the barriers listed below were areas that the research team faced, they should be seen as opportunities for future STEM-based faculty who want to conduct professional development.

Barrier #1. Before the professional development experience started, the external evaluators for the project conducted an interview protocol as a pre-measure of data collection with the eight mathematics teachers and the PPSD Mathematics Coordinator. One of the quotes from the teachers was, "I don't really have any hopes for what I'm going to get out of it [professional development]." Additionally, the mathematics teachers expressed concern over the lack of time to fit the material into their curricula and their lack of background knowledge. Classroom teachers are overworked and have extracurricular activities to lead; it is difficult for them to give time to professional development opportunities, even if they have asked to be involved in professional development. The solution to this barrier was that the research team understood the time involved for classroom; the majority of the research team were former middle and high school teachers. Therefore, the research team did not dismiss the rationales given by the teacher participants, but rather worked with them to find mutual, beneficial experiences. Although one might dismiss when professional development is held, the research team found that one of the early findings of their professional development experience was to hold weekly meetings early in the week (e.g., Tuesday). Approximately half way through the professional development experience, the same teacher who did not have any hope for a successful experience was quoted as saying, "So far, this is the best thing I've done as far as PD goes. It's taught by guys who teach the program but still understand how we can apply it every day; they always gear it towards those teachers."

Barrier #2. The language of "technology" was different for the research team and the mathematics teachers. The research team and mathematics teachers often used different terminology to describe similar concepts, which took time to decipher. For example, during one of the SolidWorks sessions, the participants worked on pattern developments (a technical drawing term) and the mathematics teachers called these same items "nets." Further, in a technical drawing scenario, one would be concerned with hems and folds, whereas the mathematics teachers were concerned with mathematical applications – they did not care how the object came together.

Barrier #3. Some of the teacher participants engaged in this professional development seemed to be more serious than others, although this was based only on the perceptions and observations of the research team. Some of the teacher participants immediately tried to implement classroom-based strategies and adjust their curricula, while others seemed to have a lesser degree of urgency. Based on the post-evaluation instruments used by the external evaluators, however, the professional development participants rated the quality of the professional development *experience* a 4.4 out of 5, and they rated the *value* of the professional development a 4.5 out of 5. Further, 100% the professional development participants said that they would recommend this professional development experience to others.

Barrier #4. Without common planning periods or time throughout the school day in addition to other curricular demands, teacher participants were less successful in applying their professional development experiences in the classroom. This was despite the research team's efforts to have multiple teachers from the same school on the professional development program and help from a district level coordinator to coordinate time. Insufficient planning time continues to be a barrier not only for this professional development experience, but also for the majority of schools in the country. One lesson learned by the research team is to consider allocating enough money into future budgets for "purchasing" teachers' time, but the research team also knows that this plan will not be sustainable based on the budgets of the LEA after the professional development experience concludes.

Barrier #5. Most teacher participants possessed a fear of moving out of their comfort zone of teaching traditional mathematics and lacked the confidence to use technology in the classroom. Nearly all of the teachers also expressed concern about how they would provide opportunities for their students to "get their hands on it" (referring to the SolidWorks software). The research team understood that access to SolidWorks and other professional development materials would be difficult for the LEA. In the case of SolidWorks, however, the research team purchased software copies for the entire LEA, so all students and teachers would have access. One of the professional development participants was quoted in the post-interview conducted by the external evaluators as saying,

> A lot of people are reluctant to go out there and do something different, but I found that is why I enjoy it. It kind of stretches my thinking and makes me rethink some of the things that I am doing that I thought were working, but I realize if I use some of the things that I see or hear in this program, it would help.

Conclusion

From the formative and limited summative assessments that the research team and external evaluators have conducted to this point in the program, there is value in professional development that challenges the traditional ways teachers teach and what they teach. "I've changed a lot of things and it's better than before. The more hands-on and visualization tools I use, the better the students understand it" (post-interview quote from teacher participant). Another teacher participant was quoted in the post-interview stating, "It has definitely given me different ideas and different ways that I can approach it – different ways that I can talk to students about what they are doing and how it can work." A different teacher was quoted as saying, "When the students can see it and visualize it, they can understand the relevance . . . and the relevance promotes rigor."

As the professional development program expands into its second year and forecasted third year, the research team is focused on implementing what they have learned from the teachers and continuing the efforts of using SolidWorks as a tool to teach teachers how to use technology to better teach geometric and trigonometric concepts. The research team feels confident that what has been documented thus far adds to the literature base on professional development, and that after the second and third year of professional development has concluded, additional literature and quantitative and qualitative results will be of benefit for not only technology educators, but also for mathematics educators. It is clear that professional development, even funded professional development, is not easy, but with sustained efforts, meaningful and productive professional development can occur.

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Networking Labs in the Online Environment: Indicators for Success

Hilmi A. Lahoud and Jack P. Krichen

Abstract

Several techniques have been used to provide hands-on educational experiences to online learners, including remote labs, simulation software, and virtual labs, which offer a more structured environment, including simulations and scheduled asynchronous access to physical resources. This exploratory study investigated how these methods can be used from the learner's perspective to enhance the online learning experience by improving its effectiveness and maintaining students' satisfaction while keeping the same level of standards and outcomes as face-to-face courses. Current and former online learners from several community and four-year colleges were surveyed to evaluate their experiences for utilizing different networking lab techniques. An analysis of survey results highlights the importance of lab accessibility to learner satisfaction and evaluates the interaction between learner experience and preference for networking labs. These results are used to recommend the best implementation practices and to guide future studies in online networking labs.

Introduction

Hands-on experience with network equipment is an essential aspect of learning computer networks, and historically it has been the mode of preparing professionals for careers in this field. It reinforces the conceptual framework of this discipline and provides the real-world experience demanded by employers in these professions (Nurul, 2006). The evolution of online learning and economic constraints have prompted the development of remote computer network laboratories and network simulation programs that closely mimic the operation of corporate computer networks (Lawson & Stackpole, 2006; Wong, Wolf, Gorinsky, & Turner, 2007) . To effectively prepare learners to transfer their learning in these environments to the enterprise, it is essential to compare the traditional network learning environment and the remote and virtual "simulated" environments. In particular, the impact of using an online learning context in conjunction with these lab scenarios must be explored because of the expanding number of online networking programs. Research exists that explores these relationships from the learner outcome perspective, but does not clearly indicate what aspects of the lab environments or learner characteristics might be related to these outcomes (Lawson & Stackpole, 2006). Because the online educational context can provide a flexible environment to accommodate individual learning characteristics, discovering these characteristics and the affect they have on learning will enable the development and maturation of more effective network labs.

Background

From the early days of distance learning, commonly referred to as Distance Education, and current online educational environments (e-learning), teaching technical courses remotely has been a challenge. Educational institutions tried different aspects of teaching remote courses using hybrid methods, including video demonstrations, offline network laboratories, and other activities utilizing both synchronous and asynchronous teaching techniques within the same course while attempting to include experiential-based learning activities. Although the importance of providing experimentally based, hands-on learning in the online environment was acknowledged, providing this experience complicated technical support, and often required that learners purchase course-related equipment to perform the activities to master network competencies (Lahoud & Tang, 2006). Therefore, it has been challenging to offer networking courses online because of the need for hands-on experience and the high cost of networking equipment, particularly if it could not be shared (Ma & Nickerson, 2006).

Technological advances during the last several years have supported the development of high-quality network simulations (Boson, 2008) and the sharing of expensive network equipment through Internet-based remote labs (Network Development Group, 2009). Remote labs became more popular because of the power of personal computers and the speed of the Internet (Border, 2007; Rigby & Dark, 2006; Schumann, 2003). According to Corter, Nickerson, Esche, Chassapis, Im, & Ma (2007), remote labs proved to be an effective tool in providing hands-on laboratory experiences to students.

As theses options became available, educational institutions, training centers, companies, and even individuals began exploring alternatives to purchasing real equipment to support computer labs. Instead, they explored simulations and remote labs for their educational and training needs (Schumann, 2003; Watts & Becker, 2008). When these alternatives evolved (i.e., remote labs and simulation software), educational institutions began to use such software to offer technical courses online. Supporting this initiative, publishers often bundle virtual labs with their textbooks to attract educational institutions to select their books (Ma & Nickerson, 2006). Educational application developers are currently using state-of-the-art software and hardware to continue to enhance remote and virtual labs and improve the fidelity of simulations to emulate equipment and provide high-quality, cost-effective solutions for networking labs.

Unfortunately, those who use simulations and remote labs often have not considered the individual differences between learners and the characteristics of labs on the success or satisfaction of the learning experience. Individual experiential differences and differences in learning styles can affect the learners' level of satisfaction and overall performance in many ways (Corter et al., 2007). According to Corter and colleagues (2007), students in engineering fields performed better in traditional settings that involved interpersonal and instructor interaction. Additionally, they were more satisfied with traditional labs than remote labs or simulation-based labs. However, little research about this issue exists relative to computer networking courses and supporting labs, particularly in the online context.

This study is an attempt to better understand how learner characteristics, particularly students' prior educational experience and career disposition, might affect their satisfaction with types of networking labs. Because the study focuses on adult learners, the tenants of adult learning theory provide the basis for the study and the analysis of the study's results. According to Adragogy, adult learning theory (Knowles, Holton, & Swanson, 2005), adults learn best and are most satisfied when learning experiences align closely with their prior life experiences. Tennant and Pogson (1995) emphasize the importance of linking to learners' prior experience; however, these authors challenge such students with learning activities to help them acquire new competencies (pp. 153–169). Adult learners prefer a more flexible learning environment where they can both reflect on the material and apply it to their lives (Tennant & Pogson, 1995, pp. 121-147). This study explored both tenants; its authors focused on the flexible online context while incorporating the experiences learners have had in both the traditional and online settings. They attempted to determine which aspects of the labs are most relevant to learner satisfaction by comparing participants with experience in networking and online education with those who had limited experience in these areas. Results that differed from those expected according to the above precepts may indicate areas for improvement in the alignment of labs to types of learners. This information could guide in the development or use of labs to improve their acceptance by students.

Online Learning and Lab Options

First, the key types of network labs will be considered. Online institutions use several options to offer experiential learning with network labs (Adams, 2004; Brown & Lahoud, 2005; Lahoud & Tang, 2006), including the following:

- Institutions provide/maintain their own labs.
- Institutions contract such task to a third party to provide such a service.
- Institutions ask learners to purchase their own simulation software to be installed on their own computers.

These options encompass several types of remote network laboratory learner experiences. However, two represent the majority of the research in this area and are most used in educational practice (Ma & Nickerson, 2006), simulation software and remote networks labs. These options are the focus of this investigation.

Simulation Software

The first category includes network simulators, similar to the Boson (2008) network simulator (NetSim™), that provides a realistic emulation of network hardware, network configuration, and realistic usage scenarios (virtual routing tables, etc.). Simulators are cost effective compared to a laboratory of network hardware and can be utilized in a shared resource environment. However, as simulations, they do not provide the exact interface and behavior that is available when using the actual hardware. This is particularly evident when exploring error conditions where a user may issue an improper or unexpected command. The real hardware will provide the actual response to the situation, but a simulation often will not provide the true response since it may represent an unexpected scenario.

The characteristics of simulators that may align with learner characteristics include fidelity or degree of similarity to the actual network environment. It is postulated that the fidelity of simulators would rank between a physical network laboratory and a remote virtual laboratory. The accessibility of the simulator is also a concern for the learner. This characteristic is related to the simulator's ability to be used on a learner's computer or accessed through a browser and Internet connection. The later use may involve an additional level of user interface. The usability of a simulator must be considered from the perspective of how accessible or intuitive is the interface.

Simulators include the option to purchase the software, and thus the student would own it after the course is finished. One of the advantages of using "owned" simulation software is the convenience of being able to perform the labs at any time without the need to schedule a time and/or access the Internet to utilize the simulation; learners are able to complete their assignments while they are traveling as long as they have access to a laptop that contains the simulation application.

Remote Labs

Remote network laboratories comprise the next group of learning environments. These laboratories support shared learner access to physical network equipment through an Internet interface. Depending on the interface used to access the hardware, this experience of configuring, maintaining, and troubleshooting a network environment is close to the experience in a true campus network (ElementK, 2008). The interface that mediates access to the physical hardware is responsible for the quality of the learner experience (Wong et al., 2007). Wong et al. (2007) indicated the interface may improve the accessibility of the labs for learners who have had little prior network experience. Additional software is often used to augment the environment through reporting services that provide a detailed analysis of network behavior (Wong et al., 2007).

Accessibility is a key consideration of these labs. Because actual network hardware is used and must be shared among learners, these laboratories are expensive. Often a reservation system is used in an online education setting to support scheduling the hardware and to control learner access; this also tracks the experience of learners who use the laboratory environment. Even though remote labs are usually used by individual learners, some remote lab settings allow learners to work on the same environment simultaneously and co-operationally, as if they were managing a real network. This provides a close representation to a traditional collaborative laboratory environment.

To mitigate expense and to improve accessibility, remote labs have been enhanced by reducing the number of required hardware components through the use of virtual software, such as VMware™ . Virtual software applications provide layers of working environments, which allows learners to install several operating systems and applications on the same computer (Golden, 2008). Even though this is a breakthrough in teaching operating systems and applications, it is still challenging when teaching configuring devices, such as routers, switches, firewalls and other network equipment.

With an understanding of the history, rationale, and characteristics of key types of network lab environments, it is now beneficial to analyze the relationship of learners' characteristics compared to each type of environment.

Methodology

Learners' satisfaction with using remote labs compared to using simulation software was evaluated from the perspective of how learner characteristics and past experience relate to preferences for a type of network lab. This study also investigated which aspects of the laboratory experience were most essential to learners and if those lab characteristics had a relationship to learner characteristics or prior experience. Learners from several online and traditional colleges and universities were invited to take an online survey. Participants were currently enrolled, were former Information Technology (IT) learners who had completed at least one online technical class, and were familiar with both online labs and simulation software. Participants completed IT-related classes from different accredited institutions, and they represent different demographics (age groups, level of education, gender, and years of experience). The names and the personal information of participants were optional. Participants were under no pressure to complete the survey. Participants were contacted via electronic mail and were given one week to complete the online survey. The survey and data were hosted online at www.speedsurvey.com. A password was needed to access the survey, and a mechanism was put into place to prevent participants from taking the survey more than one time from the same computer. Data was downloaded and analyzed using Microsoft Excel.

The survey included 10 questions that focused on the demographic, work, and educational experiences of the participants. Additionally, 13 Likert-style formatted questions were used to ascertain the participants' level of satisfaction with types and characteristics of networking labs. Two open-ended questions explored other aspects of the network lab environment. This survey is exploratory in nature and has not been validated or aligned with other instruments evaluating satisfaction with lab characteristics. It serves as a potential baseline for investigation in this area. A copy of this survey will be provided upon request.

Results

Demographics and Experience

The demographics of the participants are illustrated in Table 1. Fifty-five individuals participated in the survey, including 33 males (60%) and 22 females (40%). The majority of participants were over 31 years of age. The discipline area of the learners included: 18 IT related (33%), 16 networking (29%), 9 business (16%), and 12 in other disciplines (22%). The majority of the participants specified that networking or information technology was their discipline area: 34 (62%). However, most participants indicated general IT related 18 (33%) as their primary area of interest. As illustrated in Table 2, the participants had substantial experience in the networking profession; 34 (62%) had over three years of experience in networking technology.

Table 2. Experience in Network Technology

Years	n	Percentage
0	12	21.82%
1-2	9	16.4%
3-4	10	18.2%
5-6	6	10.91%
7 or More	18	37.2%
Total	55	100.0

From an educational experience perspective, the sample population had more experience with traditional courses than with online courses (Table 3). This table illustrates the number of both online and traditional courses taken by participants. It is apparent from that 24 (45%) had taken more than three courses in an online environment, indicating good participant background in online learning; thus, they could provide useful information for this study.

Table 3. Experience Traditional and Online Courses

	Traditional Courses		**Online Course**	
Number of Courses	*n*	%	n	%
0	0	0.0	9	16.4
1-2	13	23.6	22	40.0
3-4	23	41.8	16	29.1
5-6	12	21.8	6	10.9
7 or More	7	12.7	2	3.6
Total	55	100.0	55	100.0

As indicated in Table 4, participants also had considerable experience in networking courses; 35 (64%) had taken three or more of these courses. They also had experience with courses of all three lab types, as indicated in Table 5, but most had more experience with

Table 4. Experience Networking Courses

Courses	n	%
0	5	9.1
1-2	15	27.3
3-4	11	20.0
5 or more	24	43.6
Total	55	100.0

Table 1. Participant Characteristics

Gender:	n	%	Age Groups:	n	%	Discipline Areas:	n	%
Female	22	40.0	0-20	0	0.0	IT Related	18	32.7
Male	33	60.0	21-30	17	30.9	Networking	16	29.1
Total	55	100.0	31-40	16	29.1	Business	9	16.4
			41-50	14	25.5	Other	12	21.8
			51-60	8	14.5	Total	55	100
			Total		55	100		

Table 5. Experience Types of Labs

	Remote Lab		Traditional Lab		Simulation Lab	
Number of Courses	n	%	n	%	n	%
0	11	20.0	14	25.5	2	3.6
1-2	23	41.8	3	5.5	16	29.1
3-4	14	25.5	`7	30,9	14	25.5
5 or more	7	12.7	21	38.2	19	34.5
Total	55	100.0	55	100.0	55	100.0

traditional labs. This balance between traditional and online experience provided a good foundation for analysis of the results of this study.

Overall Perspectives on Labs

The results of this survey clarified the following questions. First, what type of network lab and what characteristics of the lab are most preferred by learners? Second, what characteristics of learners align with preferences for lab types?

To explore satisfaction with types of labs, the following questions were employed using a five-level Likert scale (1– very dissatisfied, 2 – dissatisfied, 3 – neither satisfied nor dissatisfied, 4 – satisfied, 5 – very satisfied):

- Rate your satisfaction with remote labs.

- Rate your satisfaction with traditional network labs.

- Rate your satisfaction using network simulations.

The results are represented in Figure 1. The highest satisfaction appears to be with traditional network labs, and a lower satisfaction appears to be for remote and simulation-based labs. Remote labs appeared to be more satisfying for the learners than did the simulations. Forty-three (78%) were satisfied or very satisfied with traditional labs, 35 (63%) were satisfied or very satisfied with remote labs, and 32 (58%) were satisfied or very satisfied with simulations.

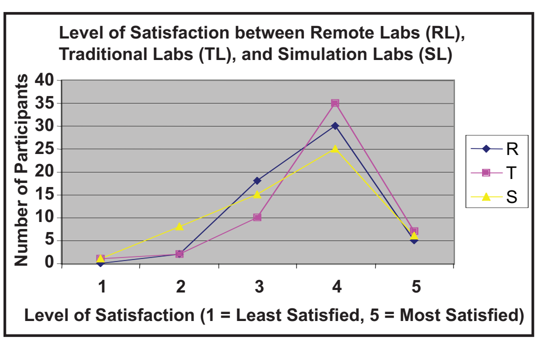

Figure 1. Overall satisfaction with lab types.

Comparing preference for types of labs within a traditional course, labs with simulations rated as most desirable 19 (35.2%), and traditional labs rated the second most desirable 17 (31.5%). It is interesting to note that learners were comfortable with remote labs: 31 (56.4%) rated them desirable, but only 9 (16.7%) rated them most desirable.

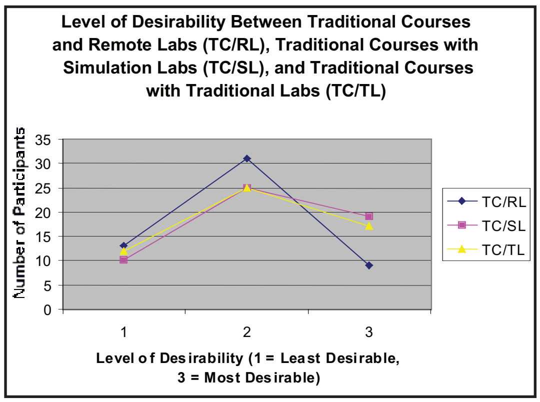

Figure 2. Lab type desirability – traditional courses.

In the online educational environment, simulation labs were also rated most desirable by 22 (40.7%) learners. Remote labs were rated second most desirable by 15 participants (27.8%). Traditional labs were least desirable, with 12 (22.2%) of participants listing them at that level. In this virtual learning environment, accessibility of labs with actual hardware, whether remote or in-person, may influence a learner's preferences for the type of lab.

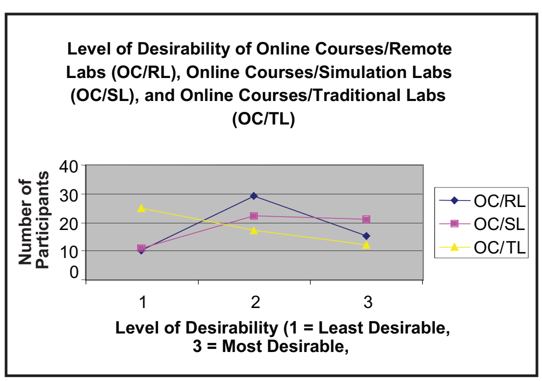

Figure 3. Lab type desirability – online courses.

Importance of Lab Characteristics

To further explore why learners preferred specific types of network labs, the importance of the characteristics of the network labs was analyzed. Responses to survey questions, illustrated in the following figures, asked learners to compare and rate f*idelity, usability,* and *accessibility* of the labs. *Fidelity* is defined as the degree to which the experience of utilizing the network equipment or simulation in the laboratory environment aligns with using it in an actual workplace environment. *Usability* is defined as the ability of learners to utilize the interface to the equipment or simulation and other features of the laboratory environment. *Accessibility* is a measure of the availability of the laboratory environment, particularly when learners desire to use it. The results seem to indicate that accessibility is the most important characteristic. In the online environment (Figure 4), accessibility was the key concern, followed by fidelity and then usability. In this environment, being able to readily access the labs appears to be more important than how well they mimic the real environment.

Considering both online and traditional courses, usability 23 (40.8%) and accessibility 18 (32.7%) were rated as important lab characteristics (Figure 5). But accessibility remains the primary concern as an essential feature of a networking lab with 21 (38.2%) rating this as essential in importance. It is surprising that fidelity ranked so low. It seems that this characteristic would be rated higher reflecting that learners prefer a more realistic network learning environment. But these results, which consider both the online and traditional environment, indicate that the ability to access and utilize the environment appears to be most important to networking learners.

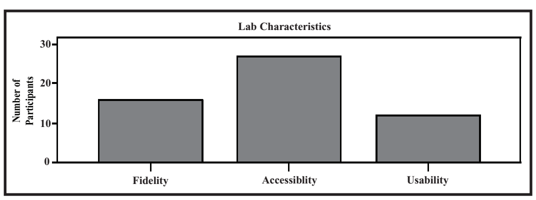

Figure 4. Lab characteristic importance in online course.

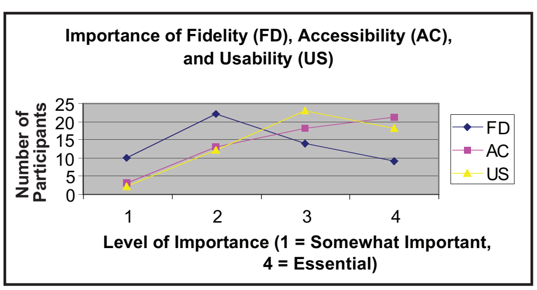

Figure 5. Lab characteristic importance in networking course.

Types of Labs as Related to Learner Characteristics

To investigate whether the prior experience of learners or their academic discipline affected their satisfaction with types of network labs, responses to survey questions rating satisfaction with laboratory types were compared with participants' work experience in networking and then with their discipline area. From the work experience perspective, participants were categorized into the following levels: (0 years, 1-2 years, 3-4 years, 5-6 years and 7 or more years). A Pearson Chi-Square analysis of the impact of experience on satisfaction for each type of lab (traditional (18.6, *df* = 16, Sig. .288), remote (14.7, *df* = 12, Sig. .258), and simulation (23.3, *df* = 16, Sig. .105) did not yield significant results. This may be partially attributed to the low number of participants (n = 55) and the requirements that each element in a Chi-Square cross-tabulation table should contain at least five counts. A visual analysis of the results, as illustrated in Figure 6, implies that learners with more experience in networking (7 or more years) favor traditional labs over simulations or remote labs (satisfied + very satisfied participants: traditional = 43, remote = 35 and simulations = 32). Although this provides some support to the notion that adult learners prefer labs that align with prior experience, the lack of a significant result implies more research in this area is needed.

From the discipline perspective, participants were categorized into IT related, networking, business and other disciplines. The expectation was that participants in the networking category would be most satisfied with traditional labs because that category would align most closely to work experience. A Pearson Chi-Square analysis of the affect that discipline has on preference for lab types did not show a significant result for traditional labs (13.204, *df* = 12, Sig. .354) or for simulations (16.04, *df* = 12, Sig. .189). However, the affect that the discipline area had on satisfaction for remote labs was borderline significant (16.886, *df* = 9, Sig. .051). Participants in the IT-related discipline indicated more satisfaction with remote labs (satisfied + very satisfied = 16) to Networking participants (satisfied + very satisfied = 9) or the other discipline areas.

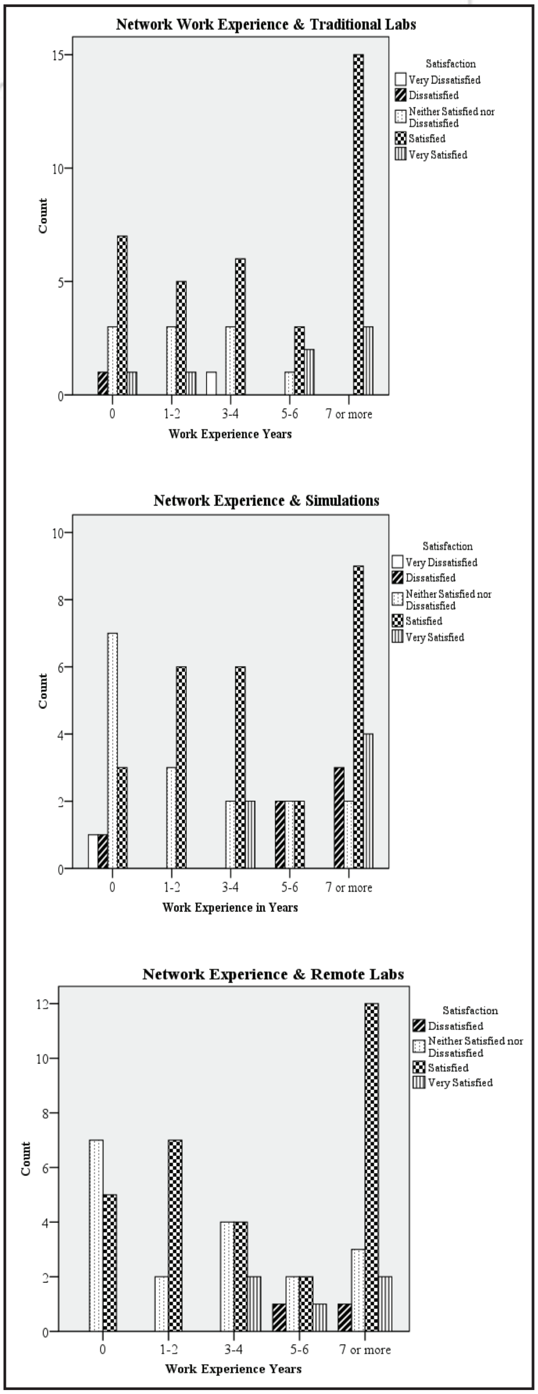

Figure 6. Lab satisfaction related to work experience.

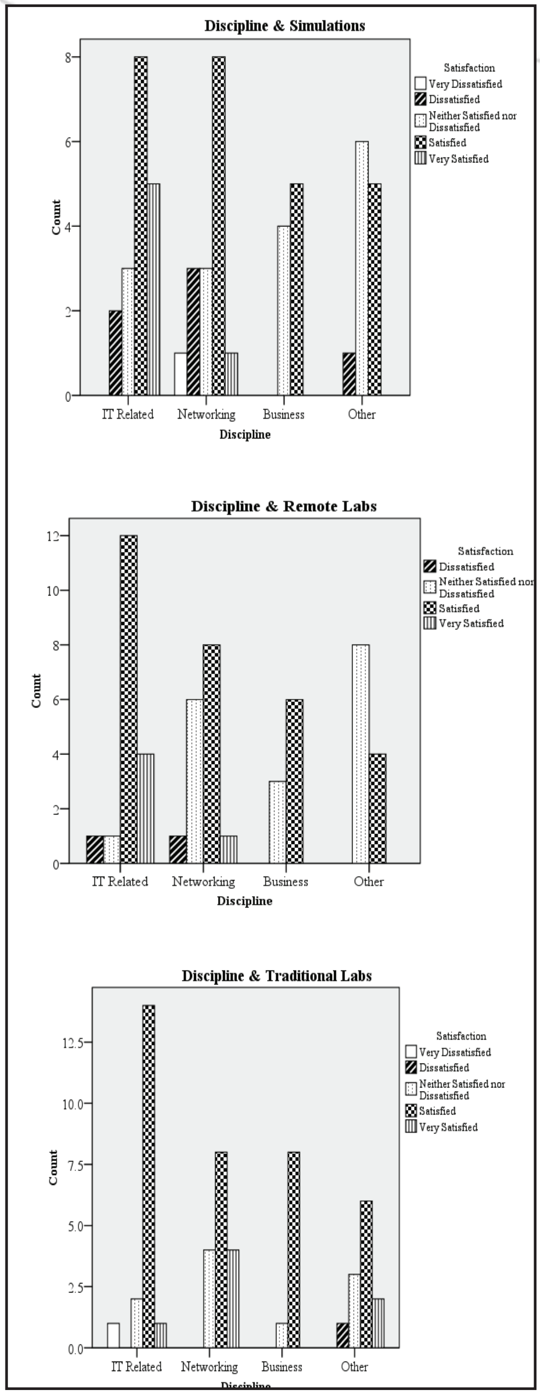

Figure7. Lab satisfaction related to discipline.

Table 6. Lab Satisfaction vs. Discipline Area

	Traditional	Remote	Simulation
IT Related	83.4%	88.9%	72.2%
Networking	75.0%	56.3%	56.3%
Business	88.9%	66.7%	55.6%
Other	66.7%	33.3%	41.7%

Note. Each cell is the percent of the count of satisfaction + very satisfied responses to the total responses for a discipline area.

Upon further inspection of the results in Table 6, it appears that learners in the academic networking discipline (i.e., networking is their specialization) preferred traditional labs (75.0% satisfied + very satisfied), but that those in related IT areas appeared to prefer remote labs (88.9% satisfied + very satisfied). However, the difference between their satisfaction levels for remote vs. traditional labs is small and inconclusive. Interestingly, learners in business also preferred traditional labs (88.0% satisfied + very satisfied), as did learners in other (non-IT) areas

(66.7% satisfied + very satisfied). The stronger satisfaction for traditional labs by networking learners would align with the perspective that labs that more closely mimic "real life" would be preferred by learners with a direct interest in this discipline area.

Limitations

As with all research, participants did not represent the entire population of students in networking courses and were limited to a few educational institutions. Laboratory types were limited to simulation software, remote labs, and traditional labs. All participants attended two-year and four-year institutions in the eastern part of the United States that offer both traditional and online courses.

Because this was an exploratory study, a unique survey was developed to determine relationships between student characteristic and lab types. This prevented direct comparisons to results of similar studies. Further, the limited sample size and the exploratory nature of the Likert scale survey questions did not warrant a statistical analysis of the data.

The questions were related to simulation labs and remote labs in general; specific vendors were not indicated. Therefore, the results do not represent any specific vendor or network hardware. Because of the lack of specific information about the lab types, the results must be interpreted from a general characteristic perspective.

Summary

This study highlighted that preference for and satisfaction with types of networking labs are related to several interconnected items, including the characteristics of the labs themselves and the characteristics of learners. The value of the study is in examining these relationships in more detail to discover implications for course design and instruction practice. Considering laboratory types in general it appears that students are more satisfied with traditional labs than remote labs or simulations. However, a different picture appears when the course room environment is considered, or when learner experience and the primary academic area of the students are considered.

In both the online and traditional course room environments, simulations were rated as more desirable then either remote or traditional labs. This seems surprising since one might assume in a traditional environment students would prefer network labs that provided direct hands-on experience with hardware. This assumption is verified to some extent by traditional labs being more desirable (by ratings) than remote labs. However additional characteristics of the lab environment seem to affect how desirable traditional labs are. This factor may be the accessibility of the lab. From the perspective of online courses and networking courses in general (Figure 4 and Figure 5), accessibility was rated the most important characteristic of networking labs. Traditional labs being less desirable may reflect difficulties that students experience in scheduling time for them and technical difficulties experienced while using them. It may reflect similar difficulties students experience when accessing remote labs via the Internet. In the online environment, remote labs were rated second in desirability to simulations, but they were rated higher than traditional labs. This reflects the desire of students to complete all coursework in the online environment, but it indicates that some aspects of the remote labs detract from their desirability in this environment.

Students who are in Networking Technology areas of study have higher levels of satisfaction (i.e., "very satisfied") than other disciplines when it comes to their experience with traditional labs. In addition, it was observed that learners in IT-related fields (not including networking), have higher levels of satisfaction with remote labs and simulation than learners in other areas of studies. The survey responses also indicate that learners with experience in networking, either through work or discipline area, prefer traditional network labs. However, there appears to be a tendency, particularly among those with less experience, to desire nontraditional labs. This may be explained by the focus on accessibility as a key desired characteristic of labs. Traditional labs may have high fidelity, and depending on the interface to remote labs, they may have high usability. However, fidelity seemed less important than being able to access the labs and complete the lab assignments. Perhaps if the accessibility of remote labs improves, fidelity may play a stronger role in satisfaction.

From a theoretical perspective, these observations align with the tenants of adult learning theory that stipulate the prior experience of the adult learner affects the learning process (i.e., they learn better when the learning experience aligns with prior work experience) (Knowles, Holton III, & Swanson, 2005). Knowles and colleagues (2005) further indicated that the motivation to learn is stronger when the learning tasks relate to the "real life" orientation of the student. Thus, one would expect that students with networking experience or whose discipline area is networking would strongly value labs with the most realistic learning experience. However, it appears that factors such as the accessibility of the labs must be improved to ensure labs of any category can provide a high-quality, desirable experience for adult learners.

To accommodate the differences in preferences for laboratory types between learners based on their level of experience and professional domain, it is recommended that a dual learning path may be most effective. For example, learners who are new to networking or who are not planning to specialize in networking from an academic or career perspective may benefit more from simulation based labs. Those more experienced with networks or who are working in this domain may relate better to remote or virtual network labs that offer an authentic network learning experience.

Recommendations

More research is required to further refine the impacts of how laboratory types and learner characteristics interact in online learning environments. Some of the research areas include studying the effect of gender on various laboratory methodologies; studying the effect of the number of job-related years of experience on the level of satisfaction of utilizing remote labs, simulation software, and traditional labs; and studying the effects of instructor involvement when offering online education courses on the level of satisfaction of learners when each one of the three lab methodologies is used.

Another study with participants from the same institutions is recommended within a year-period to determine if participants' perspectives toward network labs have changed and how the population has changed in their experiences relative to the labs and learning environments.

Computer networking and the type of networking labs used in its instruction will continue to evolve toward remote and virtual networking interfaces. As this occurs, the borders between traditional labs, remote labs, and simulations will begin to dissolve to support this migration (Gerdes & Tilley, 2007). It will be essential to explore the impact of the change of network technology, particularly virtualization, on the development and instruction of network labs on student satisfaction and learning outcomes.

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Perceived Life Satisfaction of Workplace Specialist I Faculty and Mentors Participating in a First-Year STEM Teacher Training Project

David Nickolich, Charles Feldhaus, Sam Cotton, Andrew Barrett II, and Jim Smallwood

Abstract

The purpose of this study was to measure perceived professional and personal life satisfaction of Indiana Workplace Specialist I (WS I) faculty and their mentors. Workplace Specialist I teachers are all first-year career and technical education (CTE) faculty who must complete the WS I training program to be eligible for the Workplace Specialist II teaching license. These new teachers bring significant professional skills and experience to the secondary classroom; however, none had completed traditional teachers college training before they were licensed. WS I faculty are assigned mentors during the first year of training. Mentors must have at least five years of kindergarten-12 (K-12) teaching experience, and typically they are CTE faculty members.

During a WS I / Mentor training workshop, 84 first-year WS I faculty and 68 mentors were asked to take the Life Satisfaction Index for the Third Age (LSITA) in an effort to determine perceived overall life satisfaction; 105 total people participated in the study. Of these 105, 45 mentors perceived life satisfaction as higher than did the 60 first-year WS I CTE teachers. The results of the statistical analyses revealed statistical significance at the 0.1 level (0.068).

When analyzing only participants (both mentors and WS I teachers who were 50 years of age or older, the results of the statistical analyses revealed a statistical significance at the 0.05 level (0.023) between the perceived life satisfaction results of the 10 first-year WS I faculty and the 28 mentors. Mentors who were 50 years of age or older had a higher level of perceived life satisfaction than did the first-year WS I faculty members of the same age group.

Introduction

Since the seminal report on K-12 education "A Nation at Risk" was published in 1985, the call for education reform has increased dramatically over the last 25 years. During the last nine years, the No Child Left Behind Act of 2001 (NCLB) has ensured that educators at every level focus on accountability and use scientifically based research. K-12 education policymakers have demanded that education researchers create rigorous study designs in which participants are randomly assigned to either control or experimental groups, with the aim of generating new, more credible knowledge on what works to improve student achievement.

According to Kimmelmen (2006): After nearly four years of observing schools working under NCLB, I am convinced the path to school improvement is through the process of building organizational capacity. There needs to be greater focus placed on acquiring, managing, and implementing research-based knowledge in improvement initiatives. (p. 1)

The current focus on evidence-based decision making that is based on scientific research has also brought a renewed focus on student achievement as the only outcome that matters in K-12 education. All 50 states require high-stakes tests at various grade levels, and to receive federal funds, states must develop a report card to detail student achievement in specific schools using disaggregated data that reflect various demographic variables of standardized test takers, including gender, race, and special needs status. However, the accountability movement is not the panacea that educational policymakers and researchers hoped it would be.

Rothstein, Jacobson, and Wilder (2008) stated:

> We have wound up, however, adopting accountability policies based almost exclusively on standardized test scores for reading and mathematics. To hold schools and other institutions of youth development accountable, information from tests of basic skills must be combined with a wide array of information from other sources, including tests of reasoning and critical thinking and evaluations by experienced and qualified experts who observe schools, child care centers, health clinics, and after-school

> and summer programs, to determine if they are performing satisfactorily. (p. 2)

Not all researchers and policymakers are supportive of the current focus on student outcomes based on standardized tests as the sole measure of student achievement. This intense focus has added significant pressure to all K-12 faculty and especially for STEM faculty because math and science are often included in standardized tests. In addition, educational research dealing with student achievement has eclipsed other areas of research including studies on the job and life satisfaction of teachers. Research on teachers' job and life satisfaction has been neglected despite evidence that it is a factor that should be considered (Clark, Frijters, & Shields, 2008; Easterlin, 2006). Questions remain regarding how much the accountability movement affects teachers' job and life satisfaction, and very few studies have addressed these issues.

Unwanted employee turnover is one of the largest and most costly problems organizations face. Various studies (Drizin & Hundley, 2008; Feldhaus & Hundley, 2007) report that the costs associated with employee turnover can average upwards of $25,000 per employee, because of lost productivity, loss of intellectual capital, and the direct and the indirect expenses of recruiting, selecting, and training new employees. Beyond cost is the relationship employee loyalty has on an organization's ability to serve customers and succeed in an ever-competitive global marketplace. Employee loyalty is directly associated with organizational success, which includes its impact on performance, innovation, professional life satisfaction, and retention. "Employees with low levels of professional and life satisfaction are less loyal than those who report high levels of professional and life satisfaction" (Feldhaus & Hundley, 2007).

Despite the importance of finding and keeping good employees, and the direct relationship employees have on the organization's overall ability to succeed, several K-12 school districts face challenges in retaining and motivating their science, technology, engineering, and math (STEM) workforce. According to the 2004 U.S. Dept. of Education Schools and Staffing Survey, about 66% of public schools with teacher vacancies in STEM areas (e.g., biology, physical sciences, math and technology) reported difficulty in filling those posts. This compares to only 41% reporting similar difficulties in filling English/Language Arts positions. For more than a decade, school districts across the United States have struggled to recruit and retain effective STEM faculty in general and more specifically math teachers. This problem appears to be more acute in schools serving students in high poverty populations (Boyd, Grossman, Lankford, Loeb & Wyckoff, 2006; Boyd, Grossman, & Hammerness et al., 2008; Hanushek & Rivkin, 2004). Historically, this has meant that often middle and high school STEM teachers are teaching courses that they were not in their major or minor areas of study (Ingersoll, 2003). The National Commission on Teaching and America's Future (Barnes, Crowe, & Schaefer, 2007) has estimated the cost of replacing teachers, who turn over in the early years, at $15,000 to $20,000 per teacher for the largest urban schools. The additional cost of remediation for students who lack expert teachers more than doubles that amount.

However, according to Arthur Levine, President of the Woodrow Wilson National Fellowship Foundation and former Dean of Columbia University's Teachers College, "We can help retain teachers by ameliorating the key problems that cause them to leave: poor salaries, bad working conditions, low status, and too little preparation for the classroom" (2008, p.1). This research will examine more than external conditions that affect the retention of STEM teachers, it will also address working conditions, salaries, preparation, and status. This study will examine other reasons why high school STEM faculty, especially career and technical education STEM teachers, may be satisfied with their professional and personal lives.

Purpose of the Study and Research Questions

The purpose of this study was to use participants' survey data to determine perceived satisfaction with life experiences. Overall, life satisfaction was determined by using the Life Satisfaction Index for the Third Age (LSITA) that focused on perceived life satisfaction (see Appendix A).

Three primary research questions directed this inquiry:

1. Do the mentors for the first-year Indiana CTE Workplace Specialist I teachers, as a group, have a higher life satisfaction than the group of first-year CTE Workplace Specialist I teachers, as measured by the LSITA?

2. Do the mentors, ages 50 and above, for the first-year CTE Workplace Specialist I teachers, as a group, have a higher life satisfaction than the CTE Workplace Specialist I teachers, ages 50 and above, as measured by the LSITA?

3. Do the first-year career and technical education (CTE) Workplace Specialist I teachers (as a group ages 50 and under, or as a group 50 years of age or older) or the mentors (as a group ages 50 and under, or as a group ages 50 and over) have a higher life satisfaction, as compared to the norm of the LSITA?

Review of the Literature

Recently a flurry of national reports on CTE and STEM education have been published: such titles include The Overlooked STEM Imperatives: Technology and Engineering K-12 Education (International Technology Education Association, 2009), *Tough Choices or Tough Times: The Report of the New Commission on the Skills of the American Workforce* (National Center on Education and the Economy, 2007), and Learning to Work, Working to Learn: Transforming Career and Technical Education (National Association of State Boards of Education, 2008). For the most part, these reports center on the need for dramatic change in K-12 STEM workforce and career and technical education to ensure that America maintains its competitive advantage with other countries. Some of the aforementioned reports attempted to scare the K-12 establishment into change by citing facts and figures and by drawing unfavorable comparisons between students in the United States and international students in various areas of STEM student achievement. Others use a pragmatic approach and attempted to define how applied, hands-on, project-based learning can increase student achievement in STEM subjects. Still others discussed what 21st century curricula, teacher training, assessments, career clusters, articulation agreements, workforce training, the education of parents and counselors and the benefits of CTE and STEM education should look like. In very dramatic fashion, and with much bravado and fanfare, each of the previously mentioned reports end with a “call to action” and specific recommendations for improvement.

What these reports lack is a section on teachers and their perceived professional and personal life satisfaction. Few of the most recent, high profile, nationally recognized research reports sought to gain a clear understanding of what STEM teachers in general and CTE faculty in particular want, need, expect, desire, or perceive about the very nature of the work they experience daily. After a preliminary review of the National Research Center for Career and Technical Education (NRCCTE) Web site demonstrated that there was not even a “publications by topic” devoted to the concept of “teacher satisfaction,” it became clear that additional research should be completed on this topic, and that was the impetus for this study.

Ironically, there are numerous research publications that measure CTE teachers’ perceptions on a variety of issues, including professional growth and development (Burns & Schafer, 2003; Crawford-Self, 2001; Zaleski-Burns, 2008), cultural diversity (Rehm, 2008) and the No Child Left Behind Act of 2001 (Gordon, Yocke, Moldanado, & Saddler, 2007). A comprehensive study on trends in CTE research by Rojewski, Asunda, and Kim (2008) reveals that topics of teacher recruitment and retention of CTE professionals, teacher preparation, certification, and instructional approaches were of greatest concern in this field. Research on teachers’ well-being and satisfaction was not a focal point of CTE researchers. The study found that research published in prestigious CTE research journals such as the J*ournal of Career and Technical Education, the Career and Technical Education Research Journal*, and the *Journal of Industrial Teacher Education*, could be divided into seven basic themes or topics: accountability, integration of academics and CTE, career pathways and course sequencing, articulation and transition, alternative instructional delivery, recruitment and retention of CTE professionals, and miscellaneous. Although some research on faculty perception of work and life satisfaction may be included in the “miscellaneous” category, it is evident that CTE researchers have not focused on the perceptions of CTE faculty of their professional experiences or their satisfaction with those experiences.

Despite the importance of finding and keeping good employees – and the direct relationship employees have on the organization’s overall ability to succeed – many K-12 school districts face challenges regarding retaining and motivating their workforce. CTE program administrators have also felt this faculty shortage as they attempt to fill the talent gap with CTE faculty who possess both real-world experience and teaching experience in the technology disciplines (Feldhaus & Hundley, 2007).

Mid- and second-career teacher candidates offer a prospective talent pool for the nation's schools. The potential of career changers has yet to be fully tapped, despite substantial growth in the number of programs targeting such candidates in recent years. In addition to their presumed subject matter backgrounds in high-demand disciplines, midcareer professionals who are currently a part of or choose to enter teaching can bring new maturity and experience to the nation's talent base of educators and help connect teaching and learning to expanded applications in the world of work.

Life Satisfaction Research

In an effort to continue learning about the potential for recruitment and retention of career changers who might consider becoming K-12 STEM faculty, it is important to have a clearer understanding of research that has been conducted in the area of adult education. Before investing extensively in the recruitment of existing STEM workers over the age of 50, typically called "baby boomers," some basic questions should be asked and then answered, such as the following: What is the body of research that currently exists on perceived life satisfaction? How might one find out about levels of satisfaction and happiness on the part of baby boomers? Will baby boomers be a good fit for teaching STEM subjects to K-12 students? How do younger STEM faculty compare with baby boomers in terms of personal and professional life satisfaction?

According to research (Barrett, 2005; Dychtwald, 1999; Settersten, 2002) two major current social phenomena augmented the important potential contribution that a reliable and valid index of an individual's subjective perception of successful aging can provide to researchers in Adult and Community Education, Gerontology, Psychology, Health and Medical Sciences, and other social science disciplines. These phenomena were the baby boom generation and the third age.

The "baby boom" was a result of the increase in the birth rate beginning after the end of World War II (Dychtwald, 1999). The baby boom generation was generally regarded as people born between 1946 and 1964 (Bennis & Thomas, 2002). The extraordinary number of births in the United States during this period, over 76 million, has created a population phenomenon that has affected American society at every era as this cohort has matured. The boomers are now arriving in the third age (Dychtwald, 1999).

The "third age" has been defined as the result of the extra time that has been added to the average life span since the early 1900s (Weiss & Bass, 2002) and can be thought of as beginning at the age of fifty years old and ending at death. "During the past 1000 years, our life expectancy has climbed from an average of 25 to 47 at the turn of the 20th century, and then skyrocketed to 76 today" (Dychtwald, 1999, p. 1). Many K-12 STEM faculty are currently classified as both baby boomers and residents of the third age. Recent reports (Indiana's Career and Technical Education System Report, 2007; Ingersoll, 2003; Rojewski, Asunda, & Kim, 2008) suggest that there is a looming crisis in K-12 STEM education because over 50% of the current STEM faculty will be eligible to retire in the next three years. The third age is the span of life that begins at approximately fifty years of age and ends with the start of the fourth age, which is the final stage of mind and body deterioration that ends with death (Laslett, 1996).

Statistically, the baby boom cohort began to enter the third age fifty years after 1946 or in 1996. With over 75 million adults, including native and foreign born U.S. residents, arriving at the threshold of and entering the third age measurement of subjective perceptions of success in aging, it is increasingly important to understanding the effects of the variables that impinge on their lives (Settersten, 2002). For example, a more complete understanding of the consequences of socioeconomic status, widowhood, or moving to a retirement community on older adults' perception of successful aging can help researchers and others to respond more effectively to these influences (Dychtwald, 1999; Settersten, 2002;).

According to Barrett (2005) a large and growing body of research exists that investigates what people believe makes them satisfied with their lives. A reliable and valid measure of constructs specifically related to life satisfaction in the third age or successful aging as represented in the Life Satisfaction Index for the Third Age

(LSITA) can assist researchers (Barret, 2005). An improved understanding of the contributors or barriers to a pattern of attaining increased success in life satisfaction as perceived by those going through the aging process can be facilitated by such an instrument, according to Neugarten, (1996), Lawton, (1977), and Voltz, (2003). Using such an instrument to help better understand K-12 STEM faculty might help policymakers and school administrators, as they craft new ways to recruit, retrain, reward, and retain this faculty.

Barrett (2005) developed a new instrument to measure successful aging in the third age cohort, which was titled the Life Satisfaction Index for the Third Age (LSITA). This instrument or scale was based on the theoretical framework that Neugarten and colleagues (1961) used to design the Life Satisfaction Index – Form A (LSI-A), and it was an adaptation of the LSI-A. The LSI-A was an attempt to measure perceived life satisfaction in American Midwestern adults over the age of fifty as a representation of successful aging. The construct was the concept of successful aging and the researchers called it "Life Satisfaction" (Neugarten et al., 1961).

LSI-A, according to Lawton, "is one of the most frequently used scales in the area" (1977, p. 13 as cited in Helmes, Goffin & Chrisjohn, 1998). Lawton also stated that the LSI-A has "the most careful psychometric derivation" (1977, p. 13). The LSI-A and its variants are still widely used today in such areas of research as rehabilitation and gerontology (Helmes et al., 1998). Barrett (2005) then developed specific definitions and constructs for two very important areas of the LSITA, life satisfaction, and third age.

Life satisfaction is a theoretical construct that cannot be observed directly, and it is, therefore, a latent variable. Latent variables are defined as factors that must be measured indirectly based on operational definitions (Byrne, 2001). Neugarten and colleagues, (1961) theoretical framework provided an operational definition of the latent variable of life satisfaction, which consists of the following five observed variables: zest versus apathy; resolution and fortitude; congruence between desired and achieved goals; self-concept, and mood tone.

Extensive research exists on a wide range of topics germane to career and technical education. Teacher recruitment and retention, integration of academics and CTE, career and technical student organizations (CTSOs), comprehensive school reform, underrepresented and at- risk youth, and teachers' perceptions on various issues related to CTE are common in CTE research. An educational accountability system is in place to determine program effectiveness. Lacking in the literature on CTE is research that measures the satisfaction of the personal and professional lives of STEM faculty. Also, no studies were found that compared perceptions of the satisfaction of personal and professional life of first-year CTE faculty with that of experienced teachers, 50 years of age or older, who were mentors of the first-year CTE faculty.

Method

In this study the authors measured perceived professional and personal life satisfaction of Workplace Specialist I (WS I) faculty and their mentors. WS I faculty were all first-year career and technical education (CTE) faculty who must have completed the WS I training program to be eligible for the Workplace Specialist II teaching license. WS I faculty were assigned mentors during their first year of training. Mentors were experienced CTE K-12 faculty with at least five years of teaching experience.

Instrument

The LSITA survey instrument was designed to provide a reliable and valid measure of successful aging based on the theoretical framework developed by Neugarten and her colleagues in the Kansas City Study of Adult Life in the 1960s. Their original Life Satisfaction Index – Form A (LIS-A) was updated to take advantage of the improved statistical processes. The development process of the LSITA used structural equation modeling (SEM) to measure the validity of the newly designed LSITA with Neugarten's theoretical model. The LSITA development process validated both the new instrument and the theoretical framework. The study used responses from 654 participants and established a mean score of 151.0 out of a possible 210 with a standard deviation of 19.53 as norms for the LSITA. The mean score of 151 was established as a norm for life satisfaction, as measured by the LSITA. Anyone taking the LSITA and receiving a score higher than this norm was more satisfied; a lower score would indicate less satisfaction, when comparing scores to this life satisfaction mean.

Participants

At a WS I / Mentor training workshop, a total of 84 WS I faculty and 68 mentors were asked to take the LSITA in an effort to determine perceived overall life satisfaction for novice and experienced CTE faculty. There were a total of 105 completed LSITA surveys: Forty-five experienced mentor teachers of all ages participated. Twenty-eight experienced mentor teachers and 10 first-year WS I faculty 50 years or older participated.

Table 1. Subjects That Completed All 35 items of the LSITA

Cases Included		Cases Excluded		Total	
N	Percent	N	Percent	N	Percent
105	87.5%	15	12.5%	120	100.0%

Results

Three primary research questions drove this inquiry:

1. Do the mentors for the first-year CTE WS I teachers as a group have a higher life satisfaction than the group of first-year CTE WS I teachers, as measured by the LSITA?

The results of the analyses of research question 1 are presented in Tables 2 and 3:

The results of the statistical analyses revealed a statistical significance at the 0.1 level (0.068) between the mean perceived life satisfaction results of the 60 first-year WS I faculty of all ages and the 45 experienced mentor teachers of all ages, showing that the mentors had a higher level of perceived life satisfaction than did the first year WS I faculty. There was a difference of 6.14 points in the raw score (.36 units of standard deviation). There was no statistically significant difference based on sex.

2. Do the mentors, 50 years or older, for the first-year CTE WS I teachers as a group have a higher life satisfaction than the CTE WS I teachers, 50 years or older, as measured by the LSITA?

The results of the analyses of research question 2 can be found in Tables 4 and 5. When the groups were compared by age categories (<50 and 50 and older), the mentors 50 and older had a significant difference at the 0.05 level (0.023) from the teachers 50 and older, as shown in Table 4. There was a difference of 14.24 points in the raw score that equated to .777 units of standard deviation. The overall mean was 158.43 of 210 possible on the LSITA.

Table 2. The Descriptive Statistics for LSITA Total Score for Both Teachers and Mentors

Group type	Mean	*N*	Std. Deviation	Minimum	Maximum	Range	
Teacher	155.80	60	16.59	114	185	7	
Mentor	161.94	45	17.31	110	196	86	
Total	158.43	105	17.09	110	196	86	

Table 3. The Analysis of Variance Between the Teachers and Mentors on the LSITA at the .1 Level

		Df	*F*	Sig.
LSITA Total Score	Between Groups	1	3.399	.068
	Within Groups	103		
	Total	104		

Table 4. LSITA Scores and Statistics by Age Categories

Group type	Mean	*N*	Std. Deviation	Minimum	Maximum	Range	
Teacher 50 and over	147.80	10	19.66	114	169	55	
Mentor 50 and over	162.04	28	17.85	110	194	84	
Teacher under 50	157.40	50	15.64	119	185	66	
Mentor under 50	161.79	17	16.93	124	196	72	
Total	158.43	105	17.09	110	196	86	

Table 5. The Analysis of Variance Between the Teachers 50 and over and the Mentors 50 and over on the LSITA at the .05 Level

	df	F	Sig.	
Between Groups	1	5.664	.023	
Within Groups	35			
Total	36			

The results of the statistical analyses revealed a statistical significance at the 0.05 level (0.023) between the mean perceived life satisfaction results of the 10 first-year WS I faculty 50 years or older and the 28 experienced mentor teachers 50 years or older, showing that the mentors 50 and over had a higher level of perceived life satisfaction than the first-year WS I faculty who were aged 50 and over.

3. Do the first-year CTE WS I teachers (as a group under age 50, or as a group 50 years and over) or the mentors (as a group under age 50, or as a group 50 years and over) have a higher life satisfaction, as compared to the norm of the LSITA?

The original LSITA instrument research (Barrett, 2005) used responses from 654 participants and established a mean score of 151.0 out of 210 possible with a standard deviation of 19.53 as norms for the LSITA. Table 4 shows that the results of the statistical analyses revealed that three groups in this study ("Mentor 50 and over," "Teacher under 50," and "Mentor under 50") had means higher than the LSITA norm, meaning higher life satisfaction than the norm. The "Teacher 50 and over" group has a lower mean score than the LSITA norm, meaning they have a lower perceived life satisfaction than the norm. See Table 4.

Discussion

One important finding of this study revealed that Indiana faculty who serve as mentors for first-year CTE faculty are more satisfied with their lives than the first-year CTE faculty. Many things might contribute to this finding. It is important to remember that Indiana CTE faculty who are 50 years of age or older likely started teaching in the early 1980s. This was before the "Nation at Risk" phenomenon and well in advance of the accountability movement that is now prevalent in K-12 education. It is possible that older faculty can anticipate retirement and are anxious to leave the profession. They realize that they are near the end of their professional careers and are content, and in some cases happy, about that status and the choices that come with the "third age" of life. In addition, it is possible these older faculty members are "master teachers" because they have vast and varied experiences. It is plausible that master teachers are unflappable regardless of accountability pressures placed on them. Research on teacher self-efficacy (Bandura, 1997; Guskey & Passaro, 1994; Zimmermann, 1995) would support this finding regarding master teachers.

Tschannen-Moran, Woolfolk-Hoy, and Hoy (1998, p. 203) defined teacher efficacy as a teacher's "judgment of his or her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated." We contend that CTE faculty aged 50 or older would be more apt to be efficacious than first-year CTE faculty who had never taught before. The idea that teachers' self-beliefs are determinants of teaching behavior, and ultimately perceived life satisfaction, is a simple, yet powerful idea.

Research during the past 30 years reveals that the correlates of teacher efficacy are many when using a variety of efficacy scales and measurements. Students of efficacious teachers generally have outperformed students in other classes. Teacher efficacy was predictive of student achievement on the Iowa Test of Basic Skills (Moore & Esselman, 1992), the Canadian Achievement Tests (Anderson, Greene, & Loewen, 1988), and the Ontario Assessment Instrument Pool (Ross, 1994). Additionally, greater student achievement in areas of attendance, grade point average, and persistence to graduation in rural, urban, majority black, and majority white schools for students of efficacious teachers was found by Watson (1991). Teacher efficacy is also positively correlated to students' own sense of efficacy and student motivation (Anderson et al., 1988). Regarding teacher behaviors, efficacious teachers persist with struggling students and criticize less regarding incorrect answers (Gibson & Dembo, 1984). Teachers with high efficacy tend to experiment with methods of instruction, seek improved teaching methods, and experiment with instructional materials (Allinder, 1994; Guskey, 1988). Allinder (1994) observed higher professional commitment for efficacious in-service teachers.

As a result of extensive research on teacher efficacy, it is reasonable to conclude that the successes that experienced CTE faculty have experienced over the years would contribute to their perceived life satisfaction. We also conclude that experience in teaching leads to more confidence. This study required that mentors for first-year CTE teachers have at least five years experience. It takes some faculty at least this long before feeling comfortable with teaching. We also believe that helping others (mentoring) makes one feel good, more so than mentees who rely on the help. It is possible that many mentors are good teachers and that this may have been the main reason that they were approached to be mentors. Although a speculative conclusion, these people may have a good outlook on the teaching profession and life in general.

In addition, for whatever reason, many of the WS I first-year teachers were working other jobs part-time, in addition to teaching. This could be to supplement income or to keep current in their fields of practice. Perhaps this is adding an additional level of stress that creates some life dissatisfaction.

Another finding of this study revealed that the group of mentors 50 and over had perceived life satisfaction higher than did the group of first-year WS I CTE teachers 50 years of age or older. From this result, we conclude that the pressures of teaching and the accountability movement have taken a toll on first-year CTE faculty, and even though they chronologically reside within the third age of life, these pressures overcome their experience and ability to deal with pressure and problems based on that experience. In addition, it is likely that these pressures also have affected their teacher self-efficacy and, therefore, their perceived life satisfaction.

Considering the findings of this research, the following recommendations are made:

1. It is imperative that CTE administrators not underestimate the power of experienced CTE faculty to serve as mentors, coaches, and professional role models for junior faculty.

2. It is imperative that first-year training for WS I faculty be retained and that the state of Indiana fund this initiative appropriately because it is important to the well-being of first-year faculty. Some meaningful and directed pedagogical training should be undertaken before first-year teachers are allowed to teach in the secondary classroom.

3. It is important to understand that this research found no difference in perceived life satisfaction based on gender, race, or other demographic variables. The issues here seem to relate to age and experience.

Further research should be conducted to determine if the perceived effectiveness of WS I training, or additional years of teaching, has an effect on the perceived life satisfaction of new WS I faculty. A longitudinal study that follows the WS I class of 2009 would be beneficial in an effort to determine if classroom experience has an effect on life/job satisfaction. Because the LSITA instrument has been used for many years and is valid and reliable, it would be beneficial to administer the LSITA to the WS I class of 2009 each year for a number of years to determine changes in job/life satisfaction. In addition, it may be useful to conduct similar research in other STEM areas. Although career and technical education is important, and not all CTE areas are necessarily in STEM areas, it would be useful to know how other STEM faculty perceive life satisfaction. Comparative research should be undertaken to determine if other STEM professions (e.g., medicine, physics, computer and information technology, engineering, and statistics) have similar or different results between experienced professionals and novice workers. Finally, research should be conducted to determine the relationship between teachers' self-efficacy and their perceived life satisfaction.

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Appendix A: LSITA Scale

Life Satisfaction Index for the Third Age (LSITA) Scale

Directions: There are some statements about life in general that people feel differently about. Please read each statement on the list and circle the answer that most closely reflects your attitude toward the statement above the responses. There are no right or wrong answers and your opinion on each of the statements is important. Thank you for your confidential participation in this survey.

1. As I grow older, things seem better than I thought they would be.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

2. I am frequently down in the dumps.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

3. I have gotten more of the breaks in life than most of the people I know.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

4. The best of life is behind me.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

5. I achieved in my life what I set out to do.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

6. This is the dreariest time of my life.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

7. I have been unable to do things right. The deck has been stacked against me.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

8. I am just as happy as when I was younger.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

9. I would enjoy my life more if it were not so dull.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

10. My life could be happier than it is now.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

11. As I age, I get more irritable.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

12. These are the best years of my life.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

13. I get respect for the wisdom of my age and experience.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

14. The things I do are boring or monotonous.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

15. Everything I have attempted in life has failed.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

16. I expect interesting and pleasant things to happen to me in the future.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

17. I have made both good and bad choices in my life and I can live with the results.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

18. The things I do are as interesting to me as they ever were.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

19. I feel old and tired.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

20. I am appreciated by people who know me.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

21. My life is great.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

22. I feel my age, but it does not bother me.

SStrongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

23. Everything is just great.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

24. As I look back on my life I am well satisfied.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

25. Life has not been good to me.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

26. I would not change my past life even if I could.

Strongly		Disagree	Agree	Strongly	
Disagree	Disagree	Somewhat	Somewhat	Agree	Agree

27. I enjoy everything that I do.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

28. Compared to other people my age, I have made many foolish decisions in my life.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

29. I did it my way.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

30. Compared to other people my age, I make a good appearance.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

31. I have made plans for things I will be doing a month from now.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

32. When I think back over my life, I did not get the important things I wanted.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

33. Compared to other people I often get depressed or down in the dumps.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

34. I have gotten pretty much what I expected out of life.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

35. In spite of what people say, the fate of the average person is getting worse, not better.

Strongly Disagree	Disagree	Disagree Somewhat	Agree Somewhat	Strongly Agree	Agree

** Adapted from B. L. Neugarten, R. J. Havighurst, and S. S. Tobin (1961).

Resourceful Thinking about Printing and Related Industries: Economic Considerations and Environmental Sustainability

Suanu Bliss Wikina, Cynthia Carlton Thompson, and Elinor Blackwell

Abstract

Increasing population, total economic volume, and human consumption levels have resulted in problems of resource shortages, climate change, ozone layer depletion, land regression, and deteriorating environmental pollution. Printing and related industries constitute one of the major sources of environmental pollution due to heavy energy and resource (materials) use. Therefore, there is a need to adopt resourceful thinking regarding activities in the printing and related industries, so they can contribute to environmental protection by adhering to greener, eco-friendly, and sustainable practices. This article discusses strategies that these industries could adopt, which would put their businesses on sound economic footing as they adhere to sustainable business practices that contribute to and safeguard the environment.

Introduction

Resourceful thinking about printing and related industries is much more than a focus on hardware and software acquisition in an effort to amass a profit. It is about finding the best tool to get the job done, lowering overhead costs, getting more for less, while eliminating or reducing the negative impact on the environment. As companies realize that wealth is created through technology and by adding value to natural resources, efforts need to be made to ensure that sustainable practices are put in place to protect the environment. Resourceful thinking is about meeting the challenges of creating an environment that fosters scientific discoveries and technological development. It involves the ability to know the demands of the environment, to respond to these demands with technological solutions, to create solutions that link and match the research with the actual demands of the environment, and to structure an environment that moves resourceful thinking through the global economic climate with a view of achieving the solutions needed to address business problems.

Some of the strategies that printing and related industries can use to achieve the aforementioned goals include contributing to environmental and economic sustainability; using socially conscious, environmentally friendly products and packaging; establishing safety and efficacy in product design; using renewable and recyclable resources; supporting biodegradability; promoting sustainable harvesting practices; and being accountable to present and future generations of packaging products. These strategies are addressed in detail in this article; examples are given of how they are being used successfully in the industry.

Many printing and related companies have realized that wealth is created both through technology and by adding value to natural resources. Businesses therefore are engaging in technology transfer and technology development and must set standards for sustainable and research responsibility as they relate to their companies. Such standards should include but not be limited to safety, effectiveness, research efforts, honesty regarding packaging sources and claims related to packaging; affordability, build value to equity for company, respect for the standards of the Food and Drug Administration, respect for the standards of the Federal Trade Commission, and respect for the standards of other organizations.

Technological progress is frequently sparked by creating and advancing technology, economic growth, job creation, and resourceful thinking. Resourceful thinkers are a special people who have the ability to sell or market ideas. They possess a particular set of qualities, such as vision, courage, initiative, commitment, persistence, drive, and ambition. As a result of high energy and chemical use, and associated wastes, printing and related industries constitute a major source of pollution from wastes and resources used in their production processes.

Similar to other industries, well-run printing and related businesses must use strategic goals. These goals should include “sustainability,” in terms of the business being green, renewable, and recyclable as well as profitable. Therefore, resourceful thinking about success in printing and related industries must hinge on building environmentally responsible processes that are lean, green, and sustainable while being profitable for stakeholders.

Literature Review

According to Big Sky Print (n.d.), printing is the fourth most polluting industry in the United Kingdom—the result of both high energy and high chemical use. Reducing the impact of the environment demands is more than looking beyond less energy use. It must also include making good purchasing choices. In printing and related industries, the choice of a printer and the use of recycled products must be followed by addressing both all daily activities and the design and printing processes in order to ensure sustainability. As noted by Big Sky Print (n.d.) on its website, using recycled products results in certain advantages: lower resource use, less landfills, and not harming forests. These are financial gains to the industries; however, at the same time they can result in sustainable practices with benefits to environmental protection as well as the health and safety of workers. Some of the major materials and by-products of processes in printing and related industries include the following: energy, water, wastes, emissions, and inks. The table that follows lists some steps that can be taken by printing and related industries to ensure sound environmental practices are entrenched in their companies.

Materials/By-Products	Suggested Sustainable Practices
Energy	Use 100% locally sourced renewable energy to reduce costs and environmental impacts.
Water	Reduce water usage by adopting waterless printing and by using digital processes. Also, by recycling water, harvesting rainwater, and cleaning contaminated water before disposal.
Wastes	Reuse and recycle leftovers (printing plates, ink tins, pallets, packaging) rather than dumping them into landfills.
Emissions	Eliminate use of all pre-press chemicals.
Inks	Use vegetable-based inks rather than petroleum-based inks. Vegetable-based inks are derived from vegetable oils, which are renewable resources. Inks made from them are easily removed from waste paper during de-inking. Also, pigments from vegetable-based inks do not contain heavy metals, so they are safe. Furthermore, adopt zero-alcohol printing processes.

Concerns for environmental protection and the role of printing and related industries have received global attention and are being discussed at international forums to find lasting solutions to the problem. For instance, at a forum on *Printing and the Environment* hosted by the World Printing and Communications Forum (WPCF) Organization in Dusseldorf, Germany in June, 2008, the President of the China Printing Technology Association, Yu Yongzhan, stated the steps they have taken to ensure sustainable environmental practices in the printing and related industries in China. Some of these steps include:

1. Elimination of many small-sized printing enterprises that pollute the environment through the use of outmoded technology and bad management and the emergence of large-scale backbone enterprises capable of clean production.

2. Enhancement of sustainable development capabilities.

3. Reconstruction of the traditional printing industry through application of information technology as well as the promotion and application of new-type raw and auxiliary materials.

4. Strengthened management of packaging materials and their recycling to reduce and reuse wastes as well as to make them harmless.

5. Regulations on energy-saving, emission reduction, and abandonment of laggard enterprises.

Therefore, the green revolution that has been launched in the Chinese printing industry centers around reduction of costs, processes, and energy in addition to development of value-added services, and environmental protection (Yu, 2008).Green practices have become increasingly important as companies become concerned about impacts their activities have on the environment. Therefore, printing and related industries must establish environmental management systems to show their commitment to environmental protection. Actions to consider include setting an emissions goal, being specific in communicating what has been accomplished, making products green, becoming efficient, and seeking certifications. These initiatives require ongoing commitment, should be taken seriously, and should be a key component in all business decisions (Barker, 2008). Some of these initiatives are as follows:

a. **Establishing an emissions reduction goal.** Even with no federal legislation in place to uniformly regulate emissions, companies could actively seek opportunities to reduce greenhouse gas emissions and stay ahead of the curve.

b. **Being specific in communicating accomplishments and the results achieved.** For instance, state that the company achieved a 20% reduction within five years. If the goal is stated without adding a time period, it is difficult to clearly understand the results. Also, ensure the reasons behind the accomplishments are clarified. For example, show the results emanated from improved manufacturing or production processes and/or by utilizing renewable resources and not simply reductions achieved by shutting down factories or cutting jobs.

c. **Greening products.** There is increasing demand for environmentally responsible products. Therefore, making products green will be beneficial for the business. One way to make products green is by adding recycled content to the product or its packaging. Also, removing as many hazardous chemicals as possible from the product and packaging makes it greener. This helps the bottom line as much as it helps the environment. Hazardous waste requires additional training for the staff to handle and is expensive to dispose of. These could be considered additional operating costs, but in the long run the costs are recovered via a company's good image earned by company as a result of the greening effort.

d. **Efficiency.** Lean manufacturing could be used, which decreases wastes and reduces the impact on the environment. In addition to this are the reduction in energy and water usage. These are clear demonstrations to consumers that the industries are committed to sustainability.

e. S**eek certifications.** Certifications are ways to demonstrate that the business is committed to environmental management and green practices. Examples of certifications that can be sought include the Forestry Stewardship Council (FSC) certification and the ISO 14001: 2004. The FSC awards certifications to facilities that show commitment to reducing their long-term impact on the environment by adhering to strict environmental, social, and economic standards.

Contribution to Environmental and Economic Sustainability

Many printing processes use chemicals, some of which are potentially harmful to the environment. Printing companies represent one of the more polluting industries (Blansch, 1995). Printing processes are often accompanied by pollution, which arises as an inevitable result of production processes caused by high-energy processing and the use of paper, ink, and chemicals (Masurel, 2007). Resourceful thinking about printing and related industries involves directing attention to concerns about the environment and the health of workers even as printing companies seek to make profits. As a result, "adopting environmentally friendly business practices has become an important focus for the printing industry" (Assadi, 2009, p. 18). Many printing and related industries have put in place systems to ensure that their activities cause little or no damage to the environment as well as the health and safety of their workers. An example is the Oji Paper Group (OPG), the second largest paper company in Japan.

According to Oji Paper Group (n.d.), based on information posted on its website, OPG obtains 60% of its pulp from recovered paper and the rest from its tree plantations that are managed in strict conformance to Japan's environmental standards. OPG has taken initiatives to help prevent global warming by making concerted efforts to reduce energy consumption and to switch from fossil fuel to energy generated from waste. Although OPG sets the targets of reducing both fossil energy consumption per unit of production and fossil fuel-based CO2 emissions per unit of production by 20% from the fiscal 1990 levels by 2010, it actually achieved both targets in 2006.

Based on two principles of *forest recycling* and *paper recycling*, OPG over the years has developed a sustainable recycling-oriented business model in its effort to protect and preserve the nature of the world. In terms of forest recycling, the overseas forest plantation was expanded from 200,000 to 300,000 hectares with trees already planted in over 170,000 hectares. In terms of paper recycling, the group's recovered paper utilization rate has already reached 60% with efforts to push this level higher. In addition to forest recycling and paper recycling, there are six other activities included in the group's *Action Guidelines.* These are promotion of global warming countermeasures, reinforcement of environmental improvement measures and environmental management systems, development of production technologies and products that minimize environmental impact, reduction and effective utilization of waste, transfer of environmental protection technologies to other countries, and building relationships of trust with other stakeholders.

OPG operates 16 mills in Japan and has subsidiaries and affiliates in overseas markets in Asia, Europe, and the Americas. The group annually manufactures over seven million tons of printing and writing papers, corrugated board and boxboard as well as packaging and wrapping papers, paper-based containers, thermal papers, plastics, and disposable diapers. It is also involved in the production of chemicals for paper making and packaging.

Socially Conscious, Environmentally Friendly Products and Packaging

Evidence of increasing mainstream public support for issues relating to climate change and our carbon footprint can be seen in the success of Al Gore's film, *An Inconvenient Truth.* A carbon footprint is the result of the imbalance between the collective output of carbon dioxide and other greenhouse gases by human activities and the earth's ability to process those (Parsons, 2006).

The print life cycle involves the fiber, minerals, chemicals, and energy used to make the paper, ink, and other essential materials as well as the energy and materials used in print manufacturing and distribution up to the final disposition as wastes. However, transportation of raw materials to paper mills, printer, consumer and then final disposition as well as recycling of products and the post-consumer recycled paper content are also important and should be considered aspects of sustainable product life cycle management. According to Parsons (2006), "Because printing is ubiquitous and since it is likely to remain that way, the life cycle aspects and impacts of printing and publishing are likely to come under increased scrutiny" (p. 5). The American Center for Life Cycle Assessment (ACLCA) defines a life cycle as consisting of consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal (ACLCA, n.d.).

Decisions taken at multiple stages of the printing process should therefore take into account the need for socially conscious, environmentally friendly products, as well as packaging and disposal systems that support the growing movement for environmental sustainability with regard to the printing, publishing, and related industries. A number of printers are showing commitment to co-generation and the purchase of green energy as a demonstration of the growing concern about climate change and energy security. For instance, Cenveo Anderson Lithograph, a Los Angeles-based printer generates its own electricity. In addition, the company has a system in place that captures and destroys all of the volatile organic compounds (VOC) emissions generated by its printing operations, reduces the nitrogen oxide and carbon dioxide emissions associated with combustion of natural gas fuel by as much as 85%, and produces lower emissions than the local electric utility (Parsons, 2006).

According to Assadi (2009), Greener Printer, a commercial printer, offers sustainable, eco-friendly printing and mailing services to local and national companies. The company uses technology to eliminate inefficiencies, streamline communications with customers, and make operations eco-friendly. An approach that has resulted in an immediate impact is the adoption of an all-digital workflow from the design and pre-production to proofing and delivery of files to the press. By using a Job Definition Format (JDF) to route documents through the workflow steps, this company is able to specify the ink zone settings, press setup instructions, and cutting and folding directions for JDF-enabled devices. A major advantage is that JDF-enabled PDF files speed up throughput, reduce errors, lower production costs, and conserve paper and energy. In addition, the company computerizes pre-press operations to eliminate the need for photochemicals, established a recycling program for solvents, and uses alcohol-free printing, recycled paper, low VOC inks, and energy-efficient equipment.

The Kilmer, Wagner, and Wise Paper Company, a paper and shipping products distribution company, is committed to environmental packaging. On its website, it states that all its products (corrugated cartons, bubble pack, foam, poly bags, can liners, towels, toilet tissue, Kraft wrap, starch-based flowables, etc.) are made of partial to 100% recycled materials. For example, the company claims that its flowable (PELASPAN-PAC NATURAL) is completely natural, 100% biodegradable with no CFCs and no dependence on oil, is nonstatic, non-air-polluting, renewable, recyclable, and reusable (KWW Paper, n.d.).

Establish Safety and Efficacy in Product Design

Some of the measures that can be taken to enhance safety and efficacy in the design of printing products include the use of water-based aqueous coatings to protect printed pieces. This provides a high-gloss surface that deters dirt and fingerprints and is more environmentally friendly than UV coatings. Also, inks that are vegetable-based, primarily soy, and are both gentle on the environment while producing bright, high-quality images should be used. Paper should be milled “Elemental Chlorine Free.” This is because trees are a renewable resource, but dioxin (used to bleach paper white) is permanent. UC Davis Reprographics (n.d.) stated on its website that it is committed to preserving natural resources, reducing energy usage, and reducing toxins emitted into the air. The company’s other sustainable practices include:

a. Alternative paper choices - using treeless papers made from alternative sources, such as bamboos, sugar cane, stone, and plastic. Also, the use of 100% post-consumer waste-recycled paper.

b. Online printing using Repro Graphics - placing orders, sending files, and receiving electronic proof from computer.

c. Recycling - doing this for all paper trimmings, ink, and toner cartridges.

d. On-demand printing - using digital color press.

e. Vegetable-based inks - providing for chemical-free water-based printing

Additionally, there are sustainable efforts that have been introduced to reduce wastes and to enhance the efficacy of the print production process. These include:

1. The use of eco-board poster boards - these are used to mount posters on materials made from recycled cardboard.

2. CD and DVD production - offer discs to reduce paper.

3. Poster stand rental - simply rent and reuse rather than purchasing them.

4. Environmentally friendly direct-to-plate imaging.

5. Two-sided printing - to be used as necessary; reduces paper use.

Renewable and Recyclable Resources

Recycled paper is readily used in the newsprint and packaging sectors. The use of recovered fiber in newsprint reached 87.5% in Europe in 2007, with many of the countries including the United Kingdom achieving 100% (Cox, 2009). Recycling paper is widely practiced in many businesses. In addition, companies are moving into recycling of all kinds of waste to cut costs and protect the environment. For example, ecoproducts.com stated on their website that they compost or recycle all wastes at their facility. They compost all food waste, PLA packaging scraps, food service ware, the waxed backing of UPS labels, and more. Examples of items they recycle are pallet wrap, scrap wood, scrap metal, printer cartridges, paper, co-mingled containers, and cardboard.

Biodegradability

Biodegradable products are capable of decomposing into nontoxic soil, water, carbon dioxide, and methane. The Biodegradable

Products Institute (BPI), a non-profit organization of individuals and groups from government, academic, and business sectors, has set standards for biodegradability. The institute's compostable label program has been used to educate legislators, manufacturers and consumers about the importance of scientific-based standards for biodegradable materials (BPI, n.d.).

The use of biodegradable padding materials for packaging instead of petroleum-based foam "peanuts" that are harmful to the environment is an example of a way to adopt biodegradability in fostering environmental sustainability. Several companies promote eco-friendly, biodegradable products. For instance, ecoproducts.com listed a number of "ecoproducts" on its website, including compostable paper food containers (soup cups, food containers made from corn, take-out boxes), and biodegradable bagasse soup containers.

Promote Sustainable Harvesting Practices

Efforts to promote sustainable harvesting practices are crucial for the printing industry and this could be in terms of sustainable energy harvesting as well as good harvesting practices for other products in the print life cycle. Printing requires a high amount of energy, water, paper, inks, and chemical usage. Printing and related industries should consider and adopt harvesting best practices to drive down production costs as well as to promote environmental sustainability. For instance, in the area of energy harvesting, an energy harvesting power management system capable of capturing, converting, storing, and delivering energy to power the systems. An energy harvesting system will typically be composed of a collector or transducer device. The energy collected is then converted to a form that can be used depending on whether it is for lighting (photovoltaic or solar energy), heating (thermoelectric), movement (kinetic), and so on. The final stage of the system is to condition it for storing the energy and managing it in terms of distribution to where it is needed based upon system operations or other needs in the plant.

Other best practices for sustainable harvesting could include placing trays and collection boxes at strategic points in the plants to collect recyclable materials and products, such as used ink cartridges, paper, chemicals, or water. These materials are then transported to the recycling system and new usable products are produced from them. In addition to saving costs, the impact of these best practices on the environment is beneficial to everyone. The important point is to ensure that this is communicated to everyone and periodic reports demonstrating the effectiveness of this approach as well as the gains that have been realized from it should be made known to all. This will boost morale and make everyone in the company buy into the adoption of these practices in the plant.

Present and Future Generations of Packaging Products

Considerations for the packaging of products of present and future generations require thinking about sustainability of the packaging. In terms of product packaging, the Sustainable Packaging Coalition (SPC) has defined sustainable packaging as a packaging that meets the following conditions:

a. Is beneficial, safe, and healthy for individuals and communities throughout its life cycle.

b. Meets market criteria for performance and cost.

c. Is sourced, manufactured, transported, and recycled using renewable energy.

d. Maximizes the use of renewable or recycled source materials.

e. Is manufactured using clean production technologies and best practices.

f. Is made from materials healthy in all probable ends-of-life scenarios.

g. Is physically designed to optimize materials and energy.

h. Is effectively recovered and utilized in biological and/or industrial cradle to grave cycles.

This definition is in tandem with the vision and mission of the coalition. For instance, the vision of SPC is that all packaging be responsible sourced, designed to be effective and safe throughout its life cycle, meets market criteria for performance and cost, made entirely using renewable energy, and when used is recycled efficiently to provide valuable resources for subsequent generations.

According to the Paperboard Packaging Council (PPC), sustainable advantages of using paperboard products in packaging are in terms of materials sourcing, physical design, clean production, and effective recovery. These advantages are listed as follows:

Materials sourcing. A sustainable material using specially-raised crop trees, waste products like sawdust and wood chips, and recycled paper/paperboard fibers. Sustainable wood fiber from farm-raised trees is the primary raw material in paperboard packaging. The forest products industry plants 1.7 million trees a day—planting five for every one that is harvested. Further, paperboard is recyclable, and collected fiber returns to the mill for paperboard production.

Physical design. Improved designs and manufacturing processes have reduced raw materials needed without sacrificing performance. Reduced need for labels or additional information displays—most information and brand information can be printed on paperboard. The weight of paperboard has fallen, whereas board strength has increased, allowing packages to be designed with lighter, thinner paperboard.

Clean production. Continuous improvement in production processes and new materials. Modern paperboard production has limited chemical usage and lowered air emissions in paperboard production.

Effective recovery. Paperboard packaging is a valuable resource considering that the fibers in paperboard packaging can be recycled, and usually are, multiple times. Paperboard can also be reused prior to recycling to store other materials after its contents have been used.

Summary

The main focus on resourceful thinking regarding the printing and related industries is to direct attention on ways to do things differently in order to gain economic benefits so that businesses can survive but at the same time make the world a better place for us all to live in. Resourceful thinking is about the innovative things that the printing-related industries can do to adopt sustainable business practices that could in turn yield great economic dividends.

Green businesses are very likely to succeed if there is the commitment by all stakeholders, especially the top leadership. These commitments and efforts should in turn be turned into marketing advantages for the business. Even though going green comes with some initial costs, it should be realized that these costs could in time be lower than continuing to pollute. Recycling paper, packaging, ink tins, recovering fiber, and so on and reusing them for production purposes will inevitably be less expensive than sending all these things to landfills and polluting the environment.

Going green could actually save money, create jobs, and support local communities. In order to demonstrate commitment to sustainable practices, it is important that the workforce be educated. Management must demonstrate to them that the business is serious about waste reduction and going green. If this is done, employees will be attracted to it and those that buy into the idea will come up with innovative ways to pursue these initiatives. The end result will be an increase in the bottom line of the organization. In addition, the commitment to these goals could help boost customer satisfaction efforts. Customers can feel satisfied when they are provided assistance with how to make sustainable business decisions.

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Introducing Engineering Design Through an Intelligent Rube Goldberg Implementation

Sushil Acharya and Arif Sirinterlikci

Abstract

Engineering students need a head start on designing a component, a process, or a system early in their educational endeavors, and engineering design topics need to be introduced appropriately without negatively affecting students' motivation for engineering. In ENGR1010 at Robert Morris University, freshmen engineering students are introduced to engineering design theory and practice through fun and challenging Rube Goldberg implementations to give them self-confidence early in their education. This article presents a background on Rube Goldberg mechanisms and their use in engineering education. However, the main focus is given to engineering design and microcontrollers in Rube Goldberg mechanisms. The authors worked with a multidisciplinary group of freshmen software and mechanical engineering students to complete an intelligent Rube Goldberg mechanism to assemble cheese sandwiches. The project was accomplished by using a 10-step design process and generating an automated assembly line with Rube Goldberg contraption elements controlled by a microcontroller. The Robot C programming language was employed for programming. The project details, project evaluation, and student responses are also included in this paper.

Introducing Engineering Design through an Intelligent Rube Goldberg

Implementation Background

The Accreditation Board for Engineering and Technology (ABET) and industry demand that engineering students be able to design, work in teams, and be effective communicators (Feland & Fisher, 2002). One freshman engineering course at Robert Morris University entitled, "ENGR1010: Introduction to Engineering" was revised by the authors in order to introduce engineering students to the design process through an implementation of a Rube Goldberg device. A Rube Goldberg process is used to trigger and maintain student motivation for engineering because it provides a mechanism for "learning while having fun." This design process facilitated teamwork and emphasized communication.

According to the Merriam-Webster Online Dictionary (2010) the Rube Goldberg concept is defined as "accomplishing by complex means what seemingly could be done simply." This is how Reuben Lucius Goldberg, a Pulitzer Prize-winning artist, portrayed machines and gadgets as excessive for well over 50 years. In addition, he was sometimes skeptical about the technology upon which these devices were based . His cartoons combined simple machines and common household items to create complex and wacky contraptions that accomplished trivial tasks. While most machines work to make difficult tasks simple, his designs made simple tasks

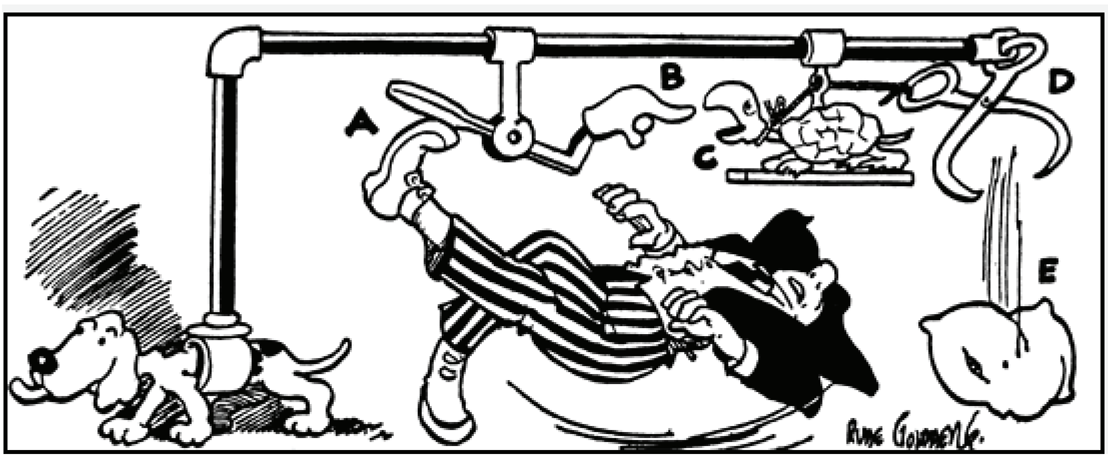

Figure 1. Safety device for walking on icy pavements: when you slip on ice your foot kicks paddle (A), lowering finger (B), snapping turtle (C) extends neck to bite finger opening ice tongs (D) and dropping pillow (E), thus allowing you to fall on something soft. (Rube Goldberg Inc., n.d.)

complex. For instance, he designed a simplified pencil sharpener, a safety device for walking on icy pavements; he dealt with problems like putting a stamp on an envelope, screwing in a light bulb, or making a cup of coffee in 20 or more steps. An example of one of his designs is illustrated in Figure 1 (Rube Goldberg Inc., n.d.).

Throughout the years more and more Rube Goldberg implementations have been seen. *"The Way Things Go,"* a 30-minute film produced in 1987 by Peter Fischli and David Weiss depicts 100 feet of physical interactions, chemical reactions, and precisely crafted chaos worthy of Rube Goldberg (Fischli & Weiss, 1987). This Rube Goldberg implementation utilized fire as the main element to drive the chain reaction. *"The Cog,"* Honda Corporation's two-minute commercial for their Accord model automobile, is yet another Rube Goldberg implementation used to present this product in an attractive way (Easton, 2005).

Rube Goldberg's work continues to connect with adult audience who are well immersed in modern technology; younger fans are also intrigued by the creativity and innovation factors involved in the designs (Phi Chapter Theta Tau and Purdue University, n.d.). Today Rube Goldberg inspires hobbies, regional and national competitions, and course-based projects in academia—examples include a playing card shuffling machine, a beverage can smashing contraption, a baby feeding mechanism, and a light bulb fitting device.

The most widely known Rube Goldberg competition is a national event held annually at Purdue University. The National Rube Goldberg Machine Contest has for 22 years invited teams of engineering students to design and build complex machines that perform basic chores. The competition brings Goldberg's inanimate cartoons to life in a way that moves students away from traditional methods of looking at problems and sends them deep into the intuitive but chaotic realm of imagination. The resulting inventions are collections of bits and pieces, parts of useless machines scraped together to achieve an innovative and imaginative contraption to resolve the problem at hand. The contest began as a rivalry between two Purdue engineering fraternities, and was popular at Purdue in the 1940s and 1950s. Since its revival in 1983, winners have appeared on various TV shows, including *Jimmy Kimmel Live, Late Night with David Letterman, NBC's Today Show, CBS's This Morning, CBS News, Beyond 2000, CNN and ABC's Good Morning America* (Phi Chapter Theta Tau and Purdue University, n.d.).

Similar mechanisms are made worldwide, but they are known by different names. In Japan, these contraptions are called "Pythagorean Devices," named after the Greek Mathematician, Pythagoras. Such devices are shown in a 15-minute educational television program for kids called, *Pythagora Switch*, which encourages children to learn and to think. In the United Kingdom, they are named after a similar cartoonist, Heath Robinson, and there they are called Heath Robinson contraptions. Likewise, in Denmark, they are called Storm P. maskiner (Storm P. machines) after the Danish animator Robert Storm Petersen (Rube Goldberg Machine, n.d.).

Argonne National Laboratory defines a successful Rube Goldberg machine (the one that is competitive in Rube Goldberg machine contests) as a machine that combines a number of objective and subjective qualities that fulfill tasks, follow rules, and impress judges (U.S. Department of Energy, n.d.). Projects that depicted the following qualities are favored by the judges in these competitions:

- The machine completes its tasks without any (highly desired) or with minimal human intervention.
- The machine's steps are clearly visible and are adequately explained during presentations.
- The machine has more antigravity power steps (highly desired) or it has a minimal number of gravity power steps.
- The machine is not entirely powered by electrical motors or uses minimal electrical power to move objects.
- The teams show strong team spirit.
- The machine incorporates adequate safety features.

Rube Goldberg in Engineering Education

At a time when the United States is looking to inspire young minds, Rube Goldberg's legacy represents the best in American innovation, humor, and unconventional thinking (Phi

Chapter Theta Tau and Purdue University, n.d.). Engineering departments in U.S. universities are using Rube Goldberg for two purposes: to expose younger students to engineering and to encourage engineering students to think outside the box. Rube Goldberg "thinking" is a great way to teach basic principles of science like magnetism, gravity, and friction. In addition, Rube Goldberg projects also promote patience and discipline, and they can assist in maintaining students' interest in science, mathematics, and engineering.

At Texas Tech University, Rube Goldberg engineering projects are used to teach students how to take an idea from paper and turn it into reality (Texas Tech University, n.d.). For the past eight fall semesters Texas Tech civil engineering students, mostly freshmen, have had a chance at devising Rube Goldberg machines. Students have carried out projects to accomplish very precise engineering tasks (e.g., leveraging a solid wooden cube onto a tall block and moving a small object two inches onto a platform). A pilot freshman curriculum has been designed and implemented in the Mechanical Engineering Department at the Rochester Institute of Technology (DeBartolo & Robinson, 2007; McGowan, 2008). The course sequence gives freshmen an overview of a broad range of mechanical engineering activities. The first course gives students most of the basic tools they will need, and the second course is centered on an electromechanical Rube Goldberg design project, undertaken by the entire class. Students develop the design concept, build the system, and prove that it works. They are able to practice skills such as communications, teamwork, time management, and experimentation. At Carnegie Mellon University, a general robotics class requires students to design simple Rube Goldberg machines (Rube Goldberg Challenge, 2006). The University of South Carolina (USC) is seeding a novel engineering curriculum in South Carolina middle and high schools as part of a national effort to expose younger students to vocational education. USC's Project Lead the Way program exhibits an elaborate Rube Goldberg apparatus in the basement of its mechanical engineering building (Garriott, 2003). Finally, at Robert Morris University Rube Goldberg implementation is utilized as a course-based project in ENGR1010, an introductory freshman engineering course.

Rube Goldberg Projects at Robert Morris University

Since the fall of 2005, the Engineering Department at Robert Morris University has assigned Rube Goldberg projects in ENGR1010: "Introduction to Engineering." Students are guided by the following constraints:

1. Minimum 15 steps are required for the mission to be completed.
2. Items easily found (not purchased) should be used as much as possible (highly desired).
3. Worth of purchased items should not exceed $50.00.
4. Minimum human intervention is encouraged and will result in higher grade (highly desired).
5. Mechanical or electrical components/devices could be used to accomplish the task.
6. Any food-related projects' products should be edible.
7. Live animals should be excluded from all designs.

Students work in teams of four or five and are required to follow a detailed engineering design and development approach. The steps of this approach are presented next:

1. *Inception (Problem Identification & Problem Statement Generation):* In this phase the teams study the problem at hand. They first gather the facts about the requirements and then they define the problem and its constraints.

2. *Conceptual Design (Alternative Concept Generation):* The teams generate alternative concepts as potential solutions. Sketches are accompanied with explanations.

3. *Product Design:* After selecting the best feasible solution, adequately labeled engineering drawings of each component and the entire product are prepared in assembly form. The Bill of Materials (B.O.M.) is completed.

4. *Product Development:* The Rube Goldberg contraption is fabricated.

5. *Product Testing & Implementation:* Adjustments are made to improve the

effectiveness of the solution during testing.

6. *Product Retirement:* Product is disassembled or displayed at the laboratories.

The teams are required to submit the following works throughout the project.

1. *Project Proposal:* The teams submit an engineering proposal consisting of a problem statement, project objectives, a preliminary B.O.M., and a plan of action. This is due one week after the project is assigned.

2. *Project Progress Updates:* The students provide a weekly update to the instructor and their team members, either via email or through prescheduled meetings. Altogether nine updates are required. In these updates the teams are required to communicate the following:
   a. What happened during the past week?
   b. What will happen this week?
   c. What are the major issues the team is facing?

3. *Project Report:* At the end of the project duration (12 academic weeks) the teams submit comprehensive project reports. Each report provides the details of how the project is executed. It contains an abstract, the project's objectives, the plan of action, a Gantt chart depicting the management plan (including tasks, resources, and timeline), and an important section on discussion and results. In this section, the students describe each step of the design and how it supported the Rube Goldberg mechanism. Students are also required to include a summary section on the project postmortem.

4. *Project Presentation:* At the end of the project duration (12 academic weeks) the teams present their product to the class and guests. The presentation consists of both a PowerPoint Presentation and a successful execution demonstration of the Rube Goldberg mechanism. Students are evaluated by the instructor and by their peers. Time durations and rules for the presentation include the following:
   a. Total Time: 15 minutes per team—10-minute PowerPoint presentation, 5 minutes for Q & A session following the presentation.
   b. Presentation of the working implementation.
      i. Explanation of each important component in detail.
      ii. Successful demonstration of the working implementation after three attempts.

Because the Rube Goldberg implementation process is heavily based on creativity, students are asked to use all of their imaginations to come up with a design that functions, is feasible within the cost constraints, and is fun to work with. In the past, students have used electricity (AC and/or DC), hydropower, robots, and simple weight-based mechanisms to build their projects.

In addition to the criteria briefly discussed previously, the students are required to accomplish the following elements:

- *Communication:* The team members are required to effectively communicate with each other to ensure the success of their project. Project proposal, team meetings, project construction, project progress updates, and the project report provide mechanisms for team communications.

- *Teamwork:* The teams are required to practice the five growth stages of a team: "Forming, Storming, Norming, Performing, and Adjourning." The teams are told that "No teamwork means no successful project" and "A successful project that lacks teamwork is a failed project." The team meetings, project construction, and project demonstration provide mechanisms for teamwork. Team members are also encouraged to bring up matters that are counterproductive to the team in a timely manner. However, they are requested to resolve these matter among themselves, and the instructor will intervene only as a last resort.

- *Recycle:* The teams are encouraged to utilize previously used items, which are easily found (but not purchased).

- *Fun Factor:* Teams are encouraged to enjoy the process as they go through the engineering design and development steps. It is believed that the fun factor helps establish ownership of the project and gives the students a passion for completing the projects.

illustrated in Figure 3. In this article, the authors present in detail an intelligent Rube Goldberg device that makes use of a VEX Robotics Development System to assemble a cheese sandwich.

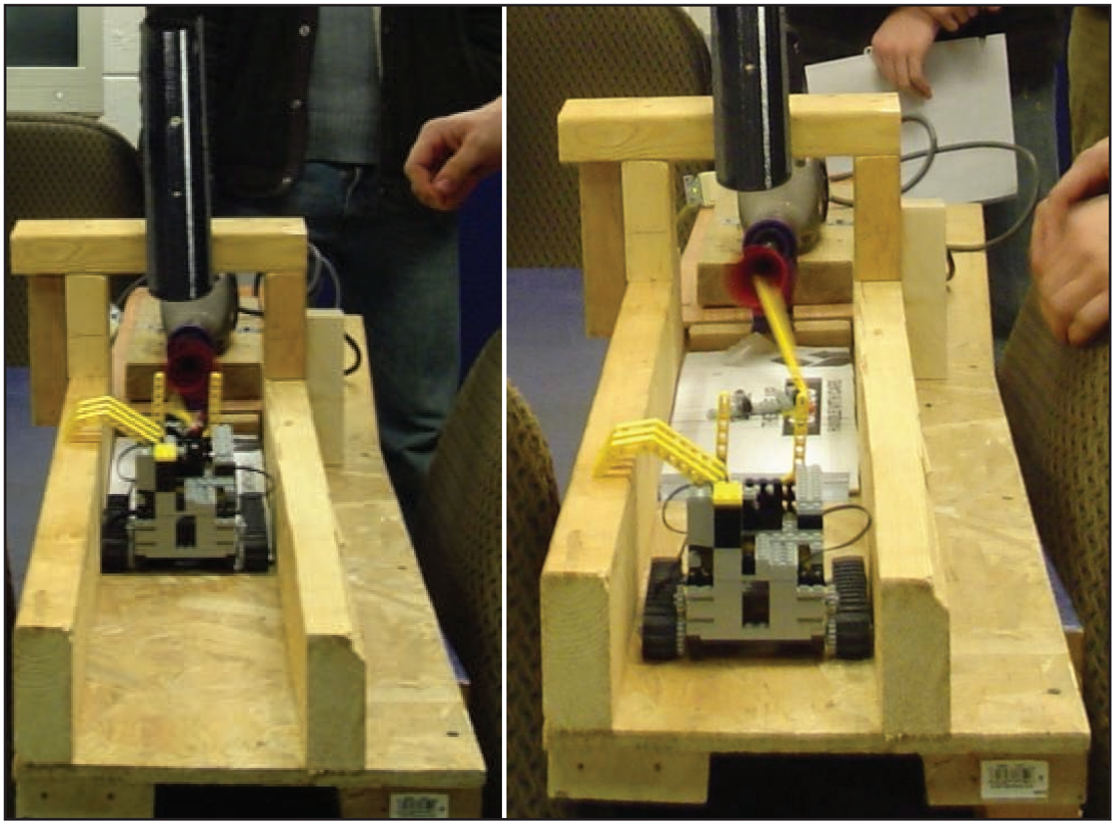

Figure 2. LEGO Mindstorms equipment being utilized for a Rube Goldberg mechanism for sharpening pencils.

Over the years, students have worked on projects that make scrambled eggs, sharpen pencils, crush empty soda cans, and assemble cheese sandwiches. A wide variety of means have been employed by the students, including robotics (as shown in Figure 2). Other project examples using more conventional means are

Figure 3. A Rube Goldberg project with conventional means used for frying eggs.

Intelligent Rube Goldberg

The Center for Intelligent Machines (n.d.) at McGill University defines intelligent machines as "machines capable of adapting their goal-oriented behavior by sensing and interpreting their environment, making decisions and plans, and then carrying out those plans using physical actions." Along the same lines the authors define an Intelligent Rube Goldberg as a machine that is capable of accomplishing a Rube Goldberg goal through physical actions initiated through the interpretation of environmental data obtained through sensors. During fall of 2008, students in ENGR1010 were assigned a Rube Goldberg project with an objective of assembling a cheese sandwich made from two slices of sandwich bread and one slice of cheese. The students were guided by the rules and requirements listed in the previous section. Ninety percent of the grade was allocated for accomplishing the given set of requirements, and 10% of the grade was designated for creativity. Although different groups used intelligences and experiences in different areas, one group decided to control the Rube Goldberg mechanism with a microcontroller meeting the definition of an Intelligent Rube Goldberg machine. The group members explained their design concept by stating, “Where most teams built a traditional elaborate mechanism, our team uses software to accomplish the task at hand.”

The authors recommended that the students use the VEX Robotics Development System. A conveyor was built using the tank threads of the VEX Robotics Development System (as shown in Figure 4). This solution was chosen due to a system’s ability of being consistent in terms of placing the bread and cheese slices at the same locations in repeated operation. This is the automation principle of repeatability. While the conveyor was driven by a DC VEX motor, dispensers were actuated by VEX servomotors. Wood and PVC were utilized in the conveyor frame and the dispensers. Along the conveyor four VEX limit switches were placed, and these would be tripped by the plate used for the sandwich assembly. Three identical dispensers were designed and placed above the conveyor for dispensing the bread slices and the cheese slice. Each dispenser operated by a servomotor that flipped the lever of the dispenser, thereby dropping the bread or cheese onto the plate. Appropriate time delays are applied before each critical activity of the control sequence. Details of the design are illustrated and explained in the following section.

The intelligent machine used the following 17 steps to meet its goal. These steps are labeled in Figure 4:

1. Flip the microcontroller switch – The machine is turned ON and the levers are reset.
2. During the 10-second interval (time delay) the machine is loaded with bread and cheese slices.
3. DC motor starts (motor[port1]) and plate begins moving along the conveyor.
4. First limit switch (touchSensor1) is triggered by the plate.
5. The conveyor belt stops.

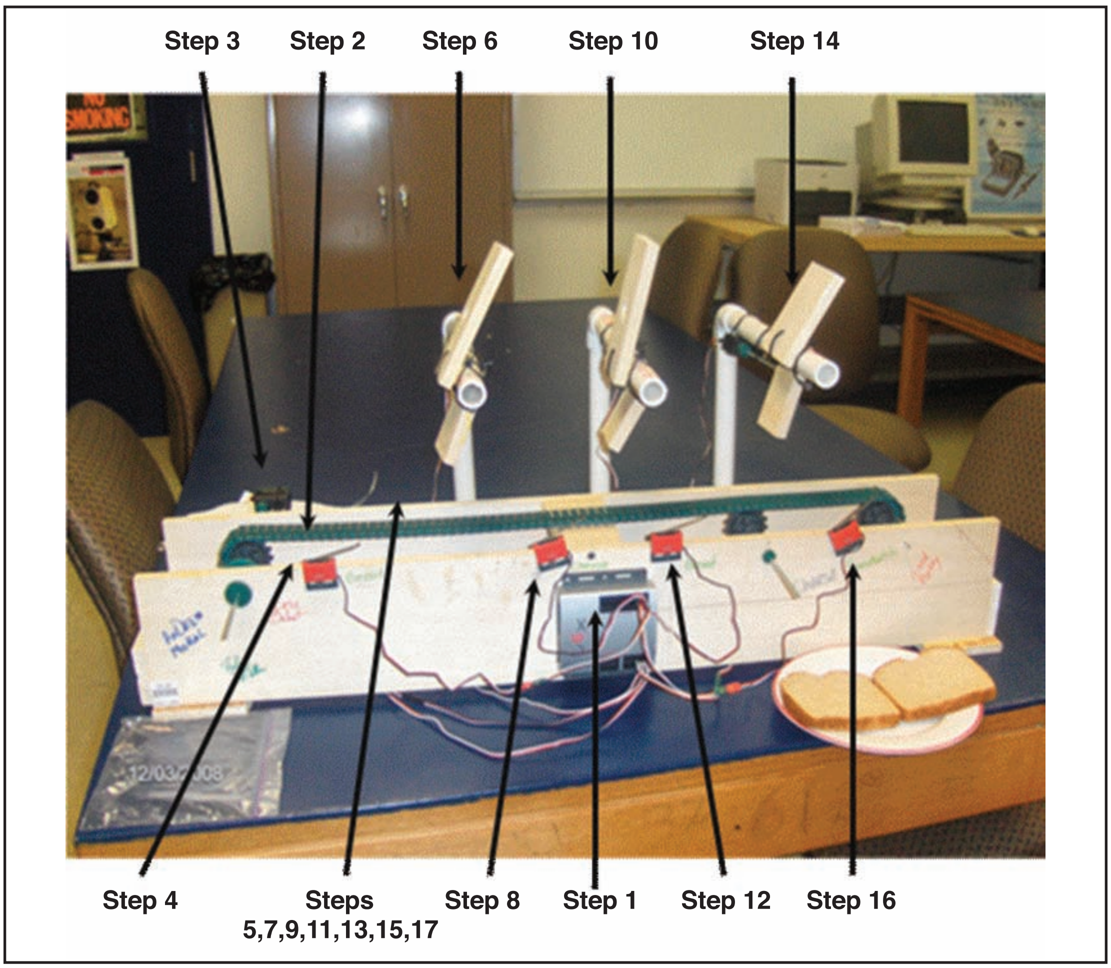

Figure 4. Intelligent Rube Goldberg mechanism/cheese sandwich assembly line.

6. The servomotor turns ON (motor[port2]), flipping the lever and the first slice of bread falls.
7. The belt begins moving again with the bread on the plate.
8. The second limit switch (touchSensor2) is triggered by the advancing plate.
9. The conveyor belt stops.
10. The second servomotor turns ON (motor[port3]), flipping the lever and the cheese slice falls.
11. The conveyor belt starts moving again with the plate, bread, and cheese.
12. The third limit switch (touchSensor3) is triggered by the advancing plate.
13. The conveyor belt stops.
14. The third servomotor turns ON (motor[port4]), flipping the lever and the second slice of bread falls.
15. The conveyor belt starts moving again, and the cheese sandwich assembly moves toward the final limit switch.
16. The fourth limit switch (touchSensor4) is tripped.
17. The conveyor stops (motor[port1]), presenting the plate and the cheese sandwich assembly at the edge of it.

A block diagram of the process is depicted in Figure 5. In terms of the programming efforts, Carnegie Mellon University's Robot C programming environment and language was used. Since one of the team members was a software engineering major, the team took advantage of his expertise in programming. The program syntax is listed in the Appendix A.

Rube Goldberg Judges' Evaluation and Students' Feedback

Based on the Argonne National Laboratory criteria listed previously, the Intelligent Rube Goldberg implementation was evaluated:

- The machine completes its tasks without any (highly desirable) or with minimal human intervention: This criterion is met. Once the program is initiated, the software modules control the overall execution of the required steps. Human intervention is not necessary.

- The machine's steps are clearly visible and are adequately explained during presentations: This criterion is met. The steps are clearly labeled in the program code as well as in the physical implementation.

- The machine has more antigravity power steps (highly desired) or with minimal number of gravity power steps: This criterion is not applicable as this implementation is executed by a controller through a program code.

- The machine is not entirely powered by electrical motors or uses minimal electrical power to move objects: This criterion contradicts the authors' definition of intelligent Rube Goldberg. Being an intelligent device, it utilizes power that is controlled through a program code.

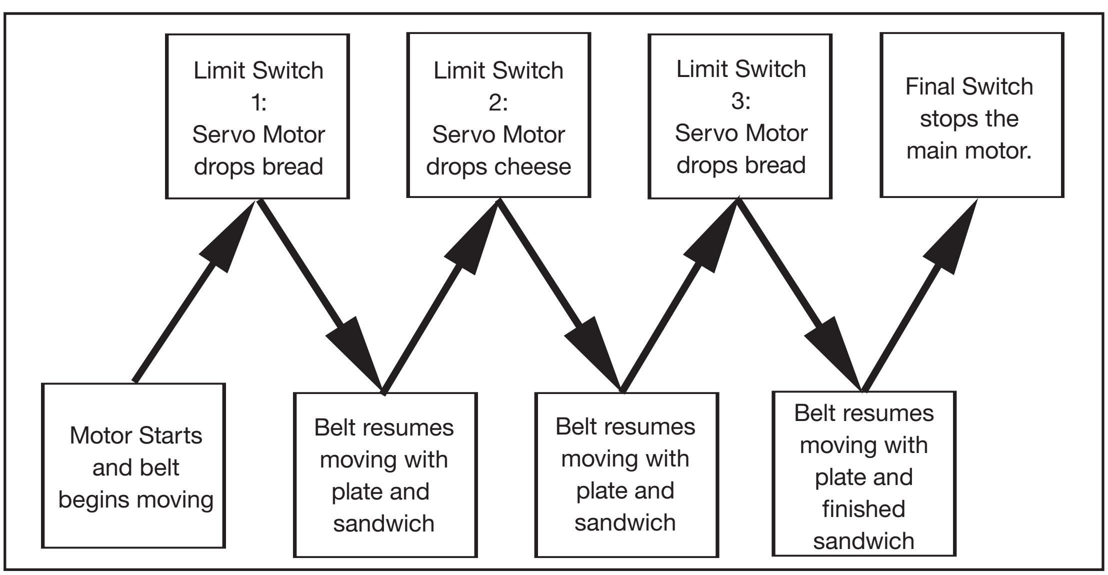

Figure 5. IBlock diagram for the logic sequence.

- The team shows strong team spirit: This criterion is met. The teamwork depicted was exceptional. The strengths and weaknesses of the team members were adequately utilized resulting in a successful implementation of the device.

- The machine incorporates adequate safety features: This criterion is met. The implementation does not provide any safety hazards due to the design and the process parameters.

At the end of the project, the students were required to perform a self/peer evaluation and project reflection. The questions asked and some of the student feedbacks are listed in Table 1:

Table 1. Student Feedback

1. What did you learn from this project experience? • I understand that communication and organization are the keys to a successful team project. • I understand that keeping control of project timelines are important. • I learned that everyone in a project does not contribute equally. • I now understand that "divide and conquer" is an important strategy in engineering projects.
2. How will you use this experience to improve personally and professionally? • I have improved my ability to communicate with people. • My time management skills have improved. • I have learned social skills required to be a team player. • I am now a better problem solver.
3. If you were to go back in time what would you do differently? • I would have insisted on more group communication. • I would encourage my team to start working on the project sooner. • I would encourage my team members to assign tasks and to be accountable. • I would spend more time on testing.

Conclusions

This intelligent Rube Goldberg project provided a unique engineering design experience for the students. Instead of using traditional devices and gadgets to accomplish the goal of making a cheese sandwich, a microcontroller with programming ability and multiple sensors were used. Students successfully accomplished the task by strictly following authors' guidelines and the recommended detailed engineering design and development approach. All required work products were submitted and presented within the deadline. Students were evaluated for communication, teamwork, recycling, and fun factors. The team communicated amongst themselves daily and with the instructor weekly. They kept a log of their communications. During the presentations team members excelled by properly explaining all the steps and then successfully demonstrating their machine. The teamwork observed by members of this team was exceptional. Roles were clearly defined and timely executed. During the course of the project all three team members remained engaged and successfully completed their allocated tasks. As previously mentioned, one member conducted the programming tasks, while the other two members designed and assembled electrical and mechanical elements of the intelligent Rube Goldberg contraption. On top of their individual roles, members also learned from the expertise of one another. The budget for this machine was minimal, and the bulk of the budget was used for fresh cheese and bread. Students borrowed the VEX Robotics Development System from the engineering laboratories and the PVC pipes and wood were picked up from scrap storage of the RMU Engineering Department. As a note on creativity, the students used VEX tank treads to develop their conveyor for the mechanism.

Student feedback during and after the learning experience were positive. The students were observed having fun while working on the project. The project was voted one of the best by the observers, and because of its compactness it is currently being used by the RMU Engineering Department as a demonstration project for visitors.

A project of this nature, where a system, a component, or a process is designed through fun-filled and challenging activities, gives students a better understanding of the work of an engineer and assists in maintaining students' interest in engineering. Students are able to capitalize on their early exposure to engineering design and related activities as they perform in other course-based projects throughout their engineering education. An early start thus enhances students' design skills and makes them more confident and competitive.

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Appendix A – Syntax of the ROBOT C program

```
task main ()
{
            motor[port2]=-127;
           motor[port3]=-127;
motor[port4]=-127;
wait1Msec(10000);
while(SensorValue(touchSensor4)==0)
{
            motor[port1]=35;
                        if(SensorValue(touchSensor1)==1)
                        {
motor[port1]=0;
motor[port2]=127;
wait1Msec(2000);
motor[port2]=-127;
wait1Msec(2000);
while(SensorValue(touchSensor4)==0)
}
motor[port1]=35;
}
}
            if(SensorValue(touchSensor2)==1)
                        {
            motor[port1]=0;
            motor[port3]=127;
            wait1Msec(2000);
            motor[port3]=-127;
            wait1Msec(2000);
            while(SensorValue(touchSensor4)==0)
            }
                        motor[port1]=35;
            }
if(SensorValue(touchSensor3)==1)
                        {
            motor[port1]=0;
            motor[port4]=127;
            wait1Msec(2000);
            motor[port4]=-127;
            wait1Msec(2000);
            while(SensorValue(touchSensor4)==0)
            }
                        motor[port1]=35;
            }
}
            }
            SensorValue(touchSensor4)=1;
Motor[port1]=0;

}
```