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TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

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THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

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An Experimental Vehicles Program Prepares Students for the Challenges of Tomorrow

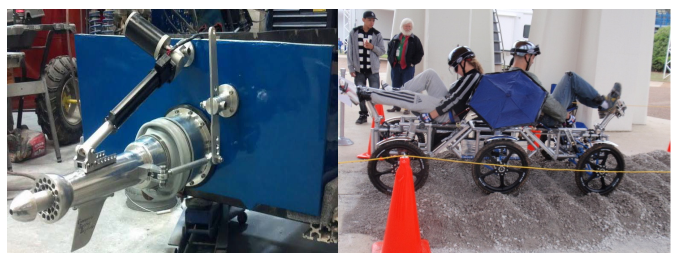
Philip Weinsier, TIIJ Editor-in-Chief

Few people can deny the benefits that STEM education brings to our youth. I'm not suggesting that every graduate will or even should work in a hands-on, technology-related field. Rather, I simply feel that it is important that students appreciate how technology works and influences their lives. Beyond just learning about technology and how to use it, I am always impressed with how young minds are able to bring concepts and theory together and produce ideas for everything from the proverbial better mousetrap to things never before conceived.

In this issue, then, the article on the experimental vehicles program at Middle Tennessee State University (MTSU) caught my attention. If there's one thing that can be said of technology and our ability to create new things, it's that we need to work that much harder to find ways of fixing all of the devices we build. Many people regularly use phrases like "obsolescence by design" and "throw-away society" to describe the world's current state of consumer devices, but I prefer to believe that we're simply practicing for better days ahead.

Many engineering technology programs do a good job of bringing knowledge to the students. Many more do a good job of building projects and transforming knowledge into products. Still others—oftentimes a function of the faculty in the given program—will make students aware of how their new skills will help them land good jobs and maybe even start their own companies. These kinds of skills can come from having students design their own start-up company right in the classroom, or taking their projects on the road to competitions with other schools. But few, in my experience, are so well rounded as to be able to provide students with all of these aspects. No, I have not visited or otherwise evaluated the programs at MTSU; but in reading this article, I am able to see that the faculty members are cognizant of these very important aspects of learning. Furthermore, in light of their experimental vehicles program (EVP), the types of projects that they are designing and building, and a 95% placement rate for their graduates, I feel that they warrant our attention and may well be a model program for us to follow.

Given the nature of MTSU's experimental vehicles program, it lends itself to the development of vehicles for competition with other schools. In fact, they compete against some of the top engineering schools in the nation. One of their designs, the solar boat, focuses on the capture, utilization, and storage of solar energy in order to power the boat. But getting to the finish line first is not the only—or possibly the most important—aspect of the competition. The students are involved in real-world design and engineering problems, and having to learn/use soft skills as a team throughout the design, construction, and testing phases of the project. MTSU reports that some of these graduates have pursued jobs in solar and alternative-energy fields.



Building a solar boat could be done using off-the-shelf components. The authors of this article tell us, however, that the team designed an innovative drivetrain for the boat; namely, one that provides adjustable trim, while simultaneously facilitating rudderless steering by integrating interchangeable motors and transom-mounted, surface-drive interchangeable sprockets for variable gear ratios and surface-piercing propellers. Another example of the innovative thinking coming out of this program is the six-wheeled Moonbuggy, designed to be a lightweight, compact, flexible, and durable all-terrain vehicle built on a carbon-fiber frame allowing for easy maneuverability in a low-gravity atmosphere. One of the more interesting designs was one that incorporated six wheels instead of four. The specially designed sectional wheels increased their strength and allowed for only the damaged portions to be replaced.

I encourage you to read this article not only because of the fascinating designs that the EVP teams come up with, but particularly for the focus that MTSU puts on preparing its technology students for the future.

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UNIVERSITY STUDENT PERCEPTIONS OF KNOWLEDGE INTO JUDGMENT TRANSFORMATIONS AND TECHNOLOGICAL LITERACY

Edward J. Lazaros, Ball State University

Abstract

This study investigated student perceptions of knowledge into Judgment transformations and technological literacy, as they relate to student learning, in a computer-applications-in-graphic-arts university core curriculum course at a large Midwestern university. The university is composed of several colleges, so student responses were used to investigate whether the students' college influenced their perceptions. Student class level and the semester in which they took the course were also variables considered in the study. Knowledge into Judgment transformations and technological literacy were investigated because the university recently started requiring these as components in some core curricular courses.

Introduction

The use of the phrase "Knowledge into Judgment" transformations has been in use since at least 2004, when the Association of American Colleges & Universities recommended that students learn to transform information into knowledge and knowledge into judgment and action [1]. Since then, however, there has been a lack of discussion and exploration of what these transformations practically look like in the classroom. Evans and Donnelly [2], however, discuss the roles of knowledge and judgment in the professional field of nursing. They use the example of a nurse working with a patient's wound. The nurse would use knowledge of wound-healing processes to determine how well the wound has healed, and that knowledge would lead to a judgment of whether the wound is healing at an appropriate rate and whether any changes need to be made [2].

Technological literacy can be defined as the ability to effectively use technology (i.e., any tool, piece of equipment or device, electronic or mechanical) to accomplish required learning tasks [3]. Since today's college students have grown up with computers, cell phones and other new technologies, professors and administrators can sometimes believe that students must already be technologically literate when they arrive on campus. However, Tanner [4] argues that this is not the case, pointing out that children most often use the Internet for entertainment. Therefore, students need to be educated on how to use the Internet and other technology in a professional manner. As an example, Tanner [4] says that social work students need to know that all client records and reports can be subpoenaed. Thus, students need to understand confidentiality laws and the fact that any report submitted online will remain online forever [4].

Davies [3] concurs, acknowledging that people become skilled with a technology only when they know how to use it; but he goes on to say that "exposure to technology does not make someone a technology expert any more than living in a library makes a person a literary expert." He also says that students generally use technology for social activities rather than academic or professional activities. In addition, although today's students are often enthusiastic about using educational technology, interest in technology is not the same as technological literacy [3].

Eisenkraft [5] studied technological literacy and interest in K-12 students, which should be of interest at the university level since these younger students will be freshmen in college at some point in the near future. The study examined 1,157 student entries to a technology innovation competition in 2006, the Toshiba/NSTA ExploraVisions competition. Two of the study's conclusions about K-12 students have particular relevance to technological literacy at the college level:

1. These students, across the board, understand that technology is more than computers and communications.
2. Some of today's top urgent technological needs (construction, energy and power) do not get the same attention from students as the more glamorous technological fields of medicine and communications [5].

Old Dominion University is an example of a school that has made technological literacy a general education requirement for all students. All students are required to take a 100-level course, which is intended "to show the many technologies that impact and are used in differing careers" [6]. Students are also required to take a 300/400-level course, which involves focused study on a particular type of technology. Ritz [6] surveyed students in these courses, and 64% of them said they had never taken a course about technology before, either in high school or the university. Thirty

-four percent of the students agreed and 34% strongly agreed that the course helped them with career selections [6].

Problem Statement

There is a lack of information relating to Knowledge into Judgment transformations and technological literacy, with regard to student learning in a computer-applications-in-graphic-arts core curriculum university course.

Purpose of the Study

The purpose of this study was to investigate the perceptions of university students with regard to Knowledge into Judgment transformations and technological literacy, as they relate to student learning in a computer-applications-in-graphic-arts core curriculum course. These perceptions will provide the faculty involved with the course with data that could influence curricular changes.

The following research questions guided this study:

1. What are the perceptions of university students with regard to Knowledge into Judgment transformations?
2. What are the perceptions of university students with regard to technological literacy?
3. Did the students' college influence their perception?
4. Did the class influence their perception?
5. Did the semester influence their perception?

The first two research questions are descriptive in nature, so there were no hypotheses to be tested. For research question three, the null hypothesis would be that there are no differences in perception for Knowledge into Judgment transformations or technological literacy for the colleges examined. The null hypothesis for research question four would be that there are no class level differences in these perceptions. Finally, for research question five, the null hypothesis would be that semester does not impact the perceptions of Knowledge into Judgment transformations or technological literacy. All statistical tests were evaluated at an alpha level of .05.

Methodology

Descriptive research was used to investigate data from university students who took a core curriculum course relating to computer applications in graphic arts in order to answer research questions one and two. For research questions three and four, which compare college- and class-level perceptions, one-way ANOVAs were used, followed by pairwise post-hoc procedures to ascertain differences. For research question five, an independent samples t-test was used to compare semester differences in perception.

Institutional Review Board (IRB) approval was received prior to conducting this study. The student responses were anonymous and confidential. The population for this study consisted of university students (N = 190) who completed computer applications in graphic arts core curriculum courses between the fall, 2010, and fall, 2011, academic semesters. The university students were grouped by their respective colleges, which consisted of Applied Sciences and Technology, College of Architecture and Planning, College of Communication, Information and Media, College of Fine Arts, College of Sciences and Humanities, Honors College, Miller College of Business, Teachers College and University College. The university students were grouped according to class, which consisted of freshman, sophomore, junior, senior, graduate or other. Furthermore, the students were grouped according to the semester in which they completed the computer applications in graphic arts course: fall, spring or summer. The response rate of the students was 94% (N=179).

The survey instrument was used to gather information of a demographic nature in three categories: 1) College; 2) Level of Completed Education; and, 3) Semester. The survey instrument was previously developed and validated by a university committee for inclusion in a university core curriculum course as an exit instrument.

The perceptions of university students with regard to Knowledge into Judgment transformations were investigated using the following questions:

1. The course helped me analyze ethical implications of using or not using knowledge.
2. The course helped me describe effective decision-making strategies.
3. The course helped me evaluate the strengths and weaknesses of arguments and actions.
4. The course helped me use multiple sources of information and knowledge to evaluate competing aesthetic forms or ideas, form judgments and provide their rationale.

The perceptions of university students with regard to technological literacy were investigated using the following questions:

1. The course promoted the use of technology.
2. The course promoted critical thinking.
3. The course helped me integrate content knowledge.
4. The course helped me reflect on my learning.

5. The course promoted the assessment of the ethical ramifications of using technology.

Results

Students were asked to indicate the name of their colleges. Fifty-one students (28.5%) were from Applied Sciences and Technology; fifty-three students (29.6%) were from the College of Communication Information and Media; nineteen students (10.6%) were from the College of Sciences and Humanities; twenty-three students (12.8%) were from the College of Business; and, thirty-three students (18.4%) were from other colleges. See Table 1 for more information.

Table 1. College in which Students Reported Being Enrolled

	n	%
Applied Sciences and Technology	51	28.5
College of Communication, Information, and Media	53	29.6
College of Sciences and Humanities	19	10.6
College of Business	23	12.8
Other	33	18.4
Total	179	100.0

Students were asked to indicate their level of completed education. Twenty-eight students (15.6%) were freshmen; sixty-five students (36.3%) were sophomores; forty-four students (24.6%) were juniors; and, forty-two students (23.5%) were seniors. See Table 2 for more information.

Table 2. Student Level of Completed Education

Classification	n	%
Freshman	28	15.6
Sophomore	65	36.3
Junior	44	24.6
Senior	42	23.5
Total	179	100.0

Students were asked to indicate the semester in which they were taking the course. One hundred and ten students (61.5%) took the course during the fall semester; sixty-nine students (38.5%) took the course during the spring semester. See Table 3 for more information.

Table 3. Semester

Classification	n	%
Freshman	28	15.6
Sophomore	65	36.3
Junior	44	24.6
Senior	42	23.5
Total	179	100.0

Students were asked to indicate whether or not the course helped them analyze ethical implications of using or not using knowledge. The percent of students that strongly agreed that the course helped them analyze ethical implications of using or not using knowledge was 49.2% (*n* = 88); 43.6% (*n* = 78) of the students somewhat agreed; and, 7.3% (*n* = 13) strongly disagreed. See Table 4 for more information.

Table 4. "The course helped me analyze ethical implications of using or not using knowledge."

Likert Scale	n	%
Strongly disagree	13	7.3
Somewhat agree	78	43.6
Strongly agree	88	49.2
Total	179	100.0

Students were asked to indicate whether or not the course helped them describe effective decision-making strategies. Most students strongly agreed that the course helped them describe effective decision-making strategies (55.9%, *n* = 100), while 35.2% (*n* = 63) somewhat agreed, and only 8.9% (*n* = 16) strongly disagreed. See Table 5 for more information.

Table 5. "The course helped me describe effective decision-making strategies."

Likert Scale	*n*	%
Strongly disagree	16	8.9
Somewhat agree	63	35.2
Strongly agree	100	55.9
Total	179	100.0

Students were asked to indicate whether or not the course helped them evaluate the strengths and weaknesses of arguments and actions. In the core curriculum course, students participate in several assignments where they must evaluate the strengths and weaknesses of arguments and actions as they solve graphic design problems presented by the instructor. Table 6 reports whether the students strongly agreed, somewhat agreed or strongly disagreed that the course helped them in evaluating the strengths and weaknesses of arguments and actions. The students strongly agreed that the course helped them evaluate the strengths and weaknesses of arguments and actions (46.4%, *n* = 83), while 38.5% (*n* = 69) somewhat agreed, and only 15.1% (*n* = 27) strongly disagreed. See Table 6 for more information.

Table 6. "The course helped me evaluate strengths and weaknesses of arguments and actions."

Likert Scale	*n*	%
Strongly disagree	16	8.9
Somewhat agree	63	35.2
Strongly agree	100	55.9
Total	179	100.0

Students were asked to indicate whether or not the course helped them use multiple sources of information and knowledge to evaluate competing aesthetic forms or ideas, form judgments and provide their rationale. Most students strongly agreed that the course helped them use multiple sources of information and knowledge to evaluate competing aesthetic forms or ideas, form judgments and provide their rationale (54.2%, $n = 97$), while 36.9% ($n = 66$) somewhat agreed, and only 8.9% ($n = 16$) strongly disagreed. See Table 7 for more information.

Table 7. "The course helped me use multiple sources of information and knowledge to evaluate competing aesthetic forms or ideas, form judgments, and provide their rationale."

Likert Scale	*n*	%
Strongly disagree	16	8.9
Somewhat agree	66	36.9
Strongly agree	97	54.2
Total	179	100.0

Students were asked to indicate whether or not the course promoted the use of technology. Most of the students strongly agreed that the course promoted the use of technology (88.8%, $n = 159$), while 8.9% ($n = 16$) somewhat agreed, and only 2.2% ($n = 4$) strongly disagreed. See Table 8 for more information.

Table 8. "The course promoted the use of technology."

Likert Scale	*n*	%
Strongly disagree	16	8.9
Somewhat agree	66	36.9
Strongly agree	97	54.2
Total	179	100.0

Students were asked to indicate whether or not the course promoted critical thinking. Most of the students strongly agreed that the course promoted critical thinking (69.8%, $n = 125$), while 24.0% ($n = 43$) somewhat agreed, and only 6.1% ($n = 11$) strongly disagreed. See Table 9 for more information.

Table 9. "The course promoted critical thinking."

Likert Scale	*n*	%
Strongly disagree	11	6.1
Somewhat agree	43	24.0
Strongly agree	125	69.8
Total	179	100.0

Students were asked to indicate whether or not the course content helped them integrate content knowledge. Most of the students strongly agreed that the course helped them integrate content knowledge (64.8%, $n = 116$), while 28.5% ($n = 51$) somewhat agreed, and only 6.1% ($n = 11$) strongly disagreed. See Table 10 for more information.

Table 10. "The course content helped me integrate content knowledge."

Likert Scale	*n*	%
Strongly disagree	11	6.1
Somewhat agree	51	28.5
Strongly agree	116	64.8
Total Completed	178	99.4
Missing	1	.6
Total	179	100.0

Students were asked to indicate whether or not the course helped them reflect on their learning. Most of the students strongly agreed that the course helped them reflect on their learning (53.1%, $n = 95$), while 36.9% ($n = 66$) somewhat agreed, and only 10.1% ($n = 18$) strongly disagreed. See Table 11 for results.

Table 11. "The course helped me reflect on my learning."

Likert Scale	*n*	%
Strongly disagree	11	6.1
Somewhat agree	51	28.5
Strongly agree	116	64.8
Total Completed	178	99.4
Missing	1	.6
Total	179	100.0

Students were asked to indicate whether or not the course promoted the assessment of the ethical ramifications of using technology. Most of the students strongly agreed that the course helped promote the assessment of ethical ramifications of using technology (64.8%, $n = 116$), while 28.5%

(n = 51) somewhat agreed, and only 6.7% (n = 12) strongly disagreed. See Table 12 for results.

Table 12. "The course promoted the assessment of the ethical ramifications of using technology."

Likert Scale	*n*	%
Strongly disagree	12	6.7
Somewhat agree	51	28.5
Strongly agree	116	64.8
Total	179	100.0

Research question #3 sought to determine whether or not the students' college influenced their perception of Knowledge into Judgment transformations and technological literacy. In order to determine if there were differences in perceptions among the colleges for Knowledge into Judgment transformations and technological literacy, a one-way ANOVA was used for each measure. The assumption of equal variances was violated for both Knowledge into Judgment transformations and technological literacy, so the Welch test was used as an alternative to the F test because it is robust to this violation. No statistically significant differences among the colleges were found for Knowledge into Judgment transformation (Welch $F_{(4,71.605)}$ = 1.31, p = .274), but technological literacy was statistically significant (Welch $F_{(4,71.987)}$ = 3.01, p = .024), indicating that there were differences among the colleges for this measure. Because of the unequal variances, a pairwise test that does not require equal variances was used as a post-hoc procedure; therefore, the Games-Howell test was chosen. Pairwise differences indicated that the College of Business was higher than the College of Communication Information and Media and other college categories for technological literacy, but no other pairwise differences were found. See Table 13 for more information.

Research question #4 sought to determine whether or not the students' class influenced their perception of Knowledge into Judgment transformations and technological literacy. To determine if there were differences in perceptions among class levels for Knowledge into Judgment transformations and technological literacy, a one-way ANOVA was used. The equal variance assumption was met for Knowledge into Judgment but was violated once again for technological literacy. There were no statistically significant overall effects found for class level, but there was evidence that there was a linear trend present in the data for both Knowledge into Judgment transformations and technological literacy when comparing the unweighted means ($F_{(1,175)}$ = 4.392, p = .038; $F_{(1,175)}$ = 5.544, p = .020, respectively). This would tend to suggest that Knowledge into Judgment transformations and technological literacy appear to decline as class level increases from freshmen through senior. Table 14 illustrates perception of Knowledge into Judgment transformations and technological literacy by class.

Table 13. "Differences in perceptions among colleges for Knowledge into Judgment transformations and technological literacy."

		N	M	SD
Knowledge into Judgment	Applied Sciences and Technology	51	2.4755	.55959
	College of Communication, Information, and Media	53	2.3443	.65454
	College of Sciences and Humanities	19	2.3947	.43554
	College of Business	23	2.5761	.38755
	Other	33	2.3258	.65098
	Total	179	2.4134	.57832
Technological Literacy	Applied Sciences and Technology	51	2.6314	.44609
	College of Communication, Information, and Media	53	2.5585	.56481
	College of Sciences and Humanities	19	2.6737	.38993
	College of Business	23	2.8174	.24800
	Other	33	2.5394	.53964
	Total	179	2.6212	.48180

Table 14. "Perception for Knowledge into Judgment transformations and technological literacy by class."

		N	M	SD
Knowledge into Judgment	Freshman	28	2.5446	.50485
	Sophomore	65	2.4385	.55732
	Junior	44	2.4659	.57716
	Senior	42	2.2321	.63292
	Total	179	2.4134	.57832
Technological Literacy	Freshman	28	2.7214	.36652
	Sophomore	65	2.6646	.43172
	Junior	44	2.6682	.48598
	Senior	42	2.4381	.57803
	Total	179	2.6212	.48180

Research question #5 sought to determine whether or not the students' semester influenced their perception for Knowledge into Judgment transformations and technological literacy. No statistically significant differences were found between fall and spring semester responses with regard to their perceptions as measured by Knowledge into Judgment transformations and technological literacy. See Table 15 for more information.

Table 15. Perception for Knowledge into Judgment Transformations and Technological Literacy by Semester

		N	M	SD
Knowledge into Judgment	Freshman	28	2.5446	.50485
	Sophomore	65	2.4385	.55732
	Junior	44	2.4659	.57716
	Senior	42	2.2321	.63292
	Total	179	2.4134	.57832
Technological Literacy	Freshman	28	2.7214	.36652
	Sophomore	65	2.6646	.43172
	Junior	44	2.6682	.48598
	Senior	42	2.4381	.57803
	Total	179	2.6212	.48180

Discussion

Prior to this study, there was a lack of information relating to Knowledge into Judgment transformations and technological literacy with regard to student learning in a computer-applications-in-graphic-arts core curriculum university course, specifically. However, prior studies have examined these topics, as described in previous literature reviews [1], [2]. This study yielded information relating to the perceptions of university students with regard to Knowledge into Judgment transformations as they relate to student learning in a computer-applications-in-graphic-arts core curriculum course, which answered research question #1. Specifically, students strongly agreed that the course helped them: analyze ethical implications of using or not using knowledge (49.1% (*n* = 88); describe effective decision-making strategies (55.9%, *n* = 100); evaluate strengths and weaknesses of arguments and actions (46.4%, *n* = 83); and, use multiple sources of information and knowledge to evaluate competing aesthetic forms or ideas, form judgments and provide their rationale (54.2%, *n* = 97). These results seem to indicate that the course is doing a good job promoting Knowledge into Judgment transformations as they relate to student learning.

With regard to technological literacy, research question #2 was answered. The students strongly agreed that: the course promoted the use of technology (88.8%, *n* = 159); promoted critical thinking (69.8%, *n* = 125); integrated content knowledge (64.8%, *n* = 116); reflected on learning (53.1%, *n* = 95); and, assessed ethical ramifications of using technology 64.8% (*n* = 116). The course appears to be doing a good job in terms of promoting technological literacy. As noted in the literature review, technological literacy is defined as "the ability to effectively use technology to accomplish required learning tasks" [3].

When research question #3 was investigated to see whether or not the students' college influenced perceptions of technological literacy, the College of Business was statistically significant (Welch $F_{(4,71.987)}$ = 3.01, p = .024), with Games-Howell pairwise tests indicating that the College of Business was higher than the College of Communication Information and Media and the other colleges. The students coming from different colleges may have had different required courses and experiences prior to this course that were related to their choice of major. This may have been an external variable. Future studies could control for prior experiences in coursework.

Research question #4 sought to determine whether or not the students' class influenced their perceptions of Knowledge into Judgment transformations and technological literacy. For both Knowledge into Judgment transformations and technological literacy, there were statistically significant linear trends found for the unweighted means. This would tend to suggest that Knowledge into Judgment transformations and technological literacy appear to decline as class level increases from freshmen through senior.

For research question #5, no statistically significant differences were found between fall and spring semester responses with regard to their perceptions as measured by Knowledge into Judgment transformations and technological literacy.

Recommendations for Further Research

Further research should be conducted to investigate why the College of Business was higher than the College of Communication Information and Media and the other colleges. Further research should also investigate why the perceptions of Knowledge into Judgment transformations and technological literacy appear to decline as class level increases from freshmen through senior. Open-ended responses should be considered in such a study.

References

[1] Leskes, A. (2004). Greater expectations and learning in the new globally engaged academy. *Peer Review, 6*(2), 4-7.

[2] Evans, R. J., & Donnelly, G. W. (2006). A model to describe the relationship between knowledge, skill, and judgment in nursing practice. *Nursing Forum, 41*(4), 150-157.

[3] Davies, R (2011). Understanding technology literacy: A framework for evaluating educational technology integration. *TechTrends: Linking Research & Practice to Improve Learning, 55*(5), 45-52.

[4] Tanner, R. (2011, November 11). The myth of the tech-savvy student. *Chronicle of Higher Education,* pp. B32-B34.

[5] Eisenkraft, A. (2010). Retrospective analysis of Technological Literacy of K-12 students in the USA. *International Journal of Technology & Design Education, 20*(3), 277-303.

[6] Ritz, J. M. (2011). A focus on Technological Literacy in higher education. *Journal of Technology Studies, 37*(1), 31-40.

Biography

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Cash-flow Simulation Game for Teaching Project Cash-flow Forecasting

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Abstract

Having a sufficient amount of cash in a construction project is critical to construction companies, and forecasting cash-flow in a construction project is, accordingly, very important. However, due to multiple factors and their impacts on cash-flow, it is not easy to teach impacts of multiple factors on cash-flow and how to forecast cash-flow in construction projects. This paper presents an educational simulation game, the Cash-flow Simulation Game, to help students in construction management programs learn how to forecast cash-flow as a supplementary method. The game simulates the physical transfer of cash among project participants and helps students visualize transactions of cash without complex calculations. The game is evaluated with regard to its applicability to teaching, based on students' perception by a questionnaire survey. The results of the questionnaire survey are discussed along with some benefits identified from the survey.

Introduction

The construction industry is notorious for its high bankruptcy rate of 20.37%, due to insufficient cash [1], and lack of liquidity is the first reason for construction companies' failure [2]. Therefore, it is very important that contractors estimate how much cash is required for construction projects in advance and to make sure this amount of cash is available during the construction phase.

Accordingly, students in construction management (CM) programs are required to learn features of cash-flow in construction projects and how to predict cash-flow for accreditation by the American Council for Construction Education [3]. Both cash inflow to a general contractor and cash outflow from a general contractor in a construction project are affected by many factors such as project owner's retainage, payment condition and progress payments. Also, cash-flow for construction projects is typically forecasted over several months. Therefore, impacts of these multiple factors on cash -flow over several months make it difficult for students in CM programs to concretize and visualize transfer of cash and predict cash-flow [4].

Game and simulation are instructional methods which encourage students' active participation [5] and have been used in construction education for teaching practical and technical skills [6]. However, no game or simulation has been developed and used for teaching cash-flow for construction projects and how to forecast cash-flow. Therefore, an educational game which simulates cash-flow to general contractors in construction projects and helps CM students visualize transfer of cash (hereafter referred to as the Cash-flow Simulation Game) was developed and played in a construction-finance-related course at one author's institution. The game is evaluated with regard to its applicability to teaching by a questionnaire survey. The purposes of this paper are to present the Cash-flow Simulation Game and to share the benefits and shortcomings of the game identified from the questionnaire survey.

Forecasting Cash-flow in Construction Education

Cash is the most important resource to contractors, who execute construction projects, and the lack of liquidity to support contractors' daily activities is one of the key reasons for contractor failure [7]. As the first requirement for securing sufficient amounts of liquidity available for construction projects, contractors need to predict cash-flow in a construction project. Accurate cash-flow forecasting provides the amount of cash needed to perform a contract. Furthermore, contractors can determine how much cash should be borrowed from financial institutions (overdraft) to cover the contract, if needed, and the amount of interest required to support the borrowed cash.

Due to the importance of cash-flow forecasting in construction projects, students in CM programs learn the features of cash-flow and how to forecast it. Also, CM programs are required to cover the subject of Forecasting Costs and Cash Flow Requirements [3] for accreditation by the American Council for Construction Education (ACCE).

Cash-flow to a general contractor in a construction project is determined and affected by several factors. First, cash-flow in a construction project is based on contract conditions. Cash-flow to a general contractor is composed of two flows: cash-in and cash-out. Cash inflows are affected by billing procedure, payment timing, project owner's retention and others which are specified in contract conditions. On the other hand, cash outflows are determined by several factors: contract conditions with subcontractors (with regard to trade financing [8] and retention), legal requirements for labor-cost payments, and payment procedures for material costs. This amount of cash to be borrowed or invested (overdraft) can be determined when all of these factors are considered and calculated.

In addition to the factors described above, teaching the features of cash-flow and forecasting cash-flow involves other topics such as Cash Trap—the difference between cash inflow and cash outflow caused by the owner's retention and delay in the owner's payment [9]—and impact of front-end-loaded Schedule of Values (SoV). Figure 1 shows the factors related to forecasting cash-flow.

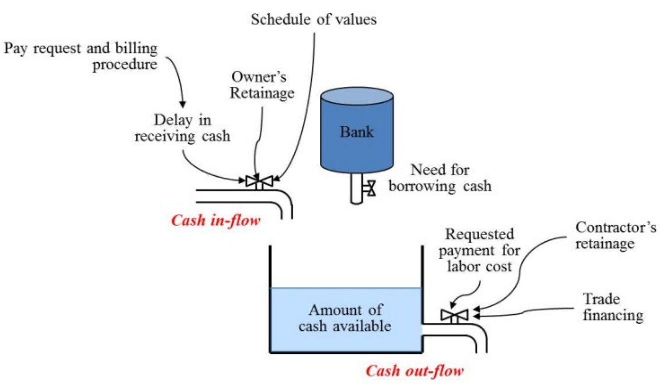

Figure 1. Influence Diagram for Cash-flow

Due to the combined impacts of several factors on cash-flow, learning cash-flow forecasting requires an understanding of the factors mentioned above and their impacts on cash-flows at first. Then, students can forecast the cash-flow of a construction project.

Teaching cash-flow forecasting may be performed in multiple approaches. The first approach is to teach rough cash-flow in construction projects based on monthly estimated cost. This approach can provide a general idea of cash-flow in construction projects; however, determination of the amount of money to be borrowed, if needed, cannot be explained under this approach. The second approach is to cover causes and features of cash-flow in construction projects. Under this approach, features and effects of the above factors on cash-flow are explained with a simple example, though how to forecast cash-flow is not covered [10], [11]. The last approach is to describe the causes and features of cash-flow and to explain how to forecast construction project cash-flows with a detailed example [2], [8].

While computer scheduling software can estimate cash-flows for a construction project, no software provides the complete set of capabilities needed for forecasting cash-flow at a project level: cost-loading activities, simultaneous loading of costs and contract values, and allowing the specifications of credit terms for payments [2]. Therefore, in the last approach described above, students can practice forecasting cash-flow in electronic spreadsheets such as Microsoft Excel at a relatively basic level. For example, the students at one author's institution are required to practice forecasting cash-flow on an Excel spreadsheet. In an example worksheet, the students are required to determine several values each month. However, it was observed that many students had difficulty calculating numbers on the spreadsheet. One of the difficulties observed was linking the multiple factors discussed earlier in the course and understanding the combined effect on cash-flow. For example, the cash -flow amount to be determined is not simply the difference between amount of cash-in (receipt amount) and amount of cash-out (payment amount). The students need to consider when they can receive cash from the project's owner and when they have to make payments to laborers, suppliers and subcontractors. However, as mentioned before, they are exposed to each of the factors separately and are expected to be able to link all of the factors and understand their combined impacts. Teaching forecasting of cash-flow requires that students understand the linkage and combined impacts of multiple factors on cash-flow, at least in an intuitive way.

Therefore, based on the authors' observations, it seems that students would need another activity, which can remind them of the previously covered topics/factors and help them link those topics altogether. While they can use Excel functions and fill handle to save time [8], the Excel functions or fill handle cannot be a substitute for understanding the combined impacts on cash-flow. Without understanding the linkage and combined impacts, working on an Excel spreadsheet with Excel functions and fill handle may make students more confused.

Game and Simulation for Enhanced Teaching

Gaming and simulation (or game-based learning) are instructional approaches in which student learning can be enhanced by active participation [5]; Weber [12] argues that the effectiveness of practice by doing is much higher than that of lecturing. In addition, the benefits of using game-based learning were identified by several researchers and educators [13] such as encouraging active learning, collaboration and interactivity.

Due to these benefits, game and simulation have been adopted in construction education. Also, it has been reported that hands-on learning is preferred by construction management students [14], [15]. Games or computer simulations were developed and used for teaching construction management courses. Some examples of the games (or simulations) developed and their focused areas are: Super-Bid for bidding skills [16]; the Equipment Replacement (*ER*) game for construction equipment replacement [17]; *CONSTRUCTO* for general management skills [18]; Negotiation game for tradeoff and negotiation skills [19]; the Parade of Trade game for impact of variability on productivity [20]; the *LEGO* Bridge game for estimating and planning [21]; the *LEAPCON* game for batch size determination [22]; and, the Poker game for risk management [23]. These games or simulations simulate real-world processes of construction projects, which help students with management-related decision making. Also, the games or simulations help students understand complex interactions among multiple construction processes.

While games or simulations have been developed for multiple areas in construction management education, no game or simulation for cash-flow or cash-flow projection in construction projects has been developed. The authors believe that forecasting cash-flow is the case in which benefits of simulation gaming for learning can be maximized because of the complex interaction and combined impacts of multiple factors. With a simulation game, students would be able to understand the linkage and impacts of multiple factors on cash-flow at an intuitive level and also practice cash-flow forecasting in a realistic setting.

The Cash-flow Simulation Game

Based on the needs for teaching and benefits of game/simulation-based learning as discussed earlier, a hands-on game was developed to help CM students forecast cash-flow in construction projects as a supplementary method. The objectives of the development of the game are: 1) to help students understand interaction and the combined impacts of multiple factors related to cash-flow; 2) to remind students of industry procedures related to cash-flow; and, 3) to help students understand the impacts of different management policies on cash-flow. Under these objectives, the model was developed with the consideration of the success factors for the development of simulation [24]. Specifically, the authors focused on: 1) consideration of the importance of human factors; 2) focus on trade-offs associated with managerial decisions and construction policies; and, 3) easy-to-use stand-alone tools.

Assumptions for the Game

One of the key factors in cash-flow in construction projects is the contract conditions regarding payment timing (billing and payment procedure) and its amount, and retention between a project's owner and a general contractor, and also between a general contractor and subcontractors (or suppliers). While particular conditions in real construction contracts may vary depending on the location, feature and type of job, the relationship between the participants and simple assumptions for the Cash-flow Simulation Game were made based on one of the textbooks [8] as follows:

- On the last day of each month, the general contractor bills the project owner for work completed during the month.
- The project owner pays the monthly bills one month after receiving bills.
- The project owner holds 10% retention.
- Final payment to the general contractor is expected to be made one month after completion of the project and to include all of the retained money.
- The general contractor withholds 10% of payments to subcontractors.
- The general contractor pays for labor costs weekly.
- The general contractor adds a markup of 20% in the bills to the project owner.
- The general contractor makes payments to suppliers and subcontractors only after receiving money from the project owner.

One of the questions general contractors have before the construction phase is how much work will be subcontracted out. One of the reasons for subcontracting is to reduce financial burdens [25]. If a portion of a project is subcontracted out under a lump-sum contract, the general contractor may use trade financing to relieve financial burden by speculating a pay-when-paid clause in the contract. To help students understand the impact of subcontracts on cash-flow, different cases with regards to different amounts of work subcontracted were developed, as shown in Table 1.

Table 1. Different Policies on Amount of Subcontracted Work

Case	Labor Cost	Subcontract Cost	Material Cost			
	$	%	$	%	$	%
I	1,400	41.2	1,200	35.3	800	23.5
II	1,800	52.9	800	23.5	800	23.5
III	800	23.5	1,800	52.9	800	23.5

Team Composition and Game Play

Each team in the game is composed of six players. Each student plays a role of a construction project participant: a project owner, a general contractor, a banker, a laborer, a material supplier or a subcontractor. The Cash-flow Simulation Game is to simulate the transfer of resources, such as materials and labor, from project participants to a building (or facility) to be constructed as the project progresses. The resources are represented by different types of stones: laborers by black stones, materials by colorful stones and subcontracted work by white stones, as shown in Figure 2.

Figure 2. Materials needed for the Cash-flow Simulation Game

Each team is provided with information about estimated cost and schedule of work. The information lets the team members know estimated cost, unit cost and schedule of work items for laborer, supplier and subcontractor. The game is to be played in multiple time frames (i.e., weeks). Each player with the role of laborer, supplier or subcontractor should determine the amount of work completed, resources allocated or materials supplied each week by rolling a die. For example, if a player has a two on his or her die, then, two becomes the amount of work completed, resources allocated or materials supplied. Then, the players need to move their own stones, which represent finished work, installed material or allocated labor to the general contractor, or hold the stones until the end of each month depending on the assumptions regarding billing and payment. The player whose role is the general contractor is required to make payments with poker chips to laborers every week and to suppliers and subcontractors every month. At the end of each month, the general contractor bills the project owner based on what has been installed (amount of stones in front of the general contractor) and moves all of the stones to the project owner. Then the project owner makes a payment to the general contractor one month after the billing and holds 10% of the billing amount as retention. When the players of subcontractor, laborer and supplier bill the general contractor, and when the general contractor bills the project owner, they need to calculate the amount of billing based on the number from the dice and the unit cost, and write the amount on a billing sheet. Finally, the billing sheets (bills) are transferred to the general contractor or the project owner along with stones.

The general contractor is required to calculate balance in the cash account at the end of every transaction of poker chips. If the player does not have enough cash for payments, then the general contractor has to borrow poker chips (cash) from the banker. In order to record the balance, the general contractor is given an empty chart for cash balance and has to keep its record. Each round of the game is over when all of the resources (or stones) are transferred to the project owner and all of the suppliers, laborers and subcontractors are paid by the general contractor.

The Cash-flow Simulation Game developed in this study has the following features:

- Simple and easy to follow: this game simply simulates transactions of work, service, materials and cash in real construction projects with stones and poker chips. Therefore, it is very straightforward in visualizing transactions of resources and cash among project participants.
- Minimized calculations: by transferring poker chips (representing cash) and stones (representing resources), the players don't need to calculate the amount of work (service or material) provided every week. Calculation of billing and payment amounts is based on the number of stones in front of the players.
- Easy identification of the maximum amount of cash to be borrowed (or invested): the general contractor needs to keep a record of the cash balance at the end of each transaction on the given sheet. This data on a plot enables the students to easily find the minimum balance or the maximum amount of cash to be borrowed (or invested).
- Consideration of uncertainty in construction execution: amount of work (or service) completed (or provided) and the amount of materials supplied each week are determined by rolling a die. This process reflects the uncertainties in the amount of labor available, construction productivity and material supply.
- Easy comparison of impacts of different policies: the game is planned to be played in three rounds with different policies regarding payment timing and schedule of values. The result in the general contractor's minimum balance from each round can be easily compared from other rounds, and students can identify and discuss the impacts easily.

Implementation of the Game

The Cash-flow Simulation Game was implemented in the Construction Finance and Accounting class in the fall, 2011, semester after a pilot study in the previous semester at one author's institution. A total of 35 students in six teams (5 teams with 6 members and one team with 5 members) participated in the game.

It took about 20-25 minutes to complete one round of the game. All of the six teams finished the first round and recorded the change in the general contractors' balance as exemplified in Figure 3. Then, they could determine the minimum balance (or the maximum amount of cash to be borrowed or invested) from the plot. Also, the students discussed the impact of the amount of subcontracted work on cash-flow based on their plots.

Evaluation of the Game

The Cash-flow Simulation Game was evaluated with regards to its applicability to teaching by a questionnaire survey. This survey was taken and completed by the students who participated in the game. The questions in the survey asked about the students' perception on the helpfulness of the game in their learning. The results are summarized in Figure 4. Based on the results, it can be concluded that the game is helpful for the students to understand the topics related to cash-flow in construction projects and forecasting cash-flow. Positive responses (sum of *Strongly Agree* and *Moderately Agree*) for each question are 100% for typical billing procedures (question 1), 96.97% for *cash trap* (question 2), 69.69% for impact of front-end-loaded SoV on cash-flow (question 3), 93.94% for impact of different policies on cash-flow (question 4), and 96.97% for overall cash-flow (question 4), 72.72% for helpfulness on forecasting cash-flow on spreadsheet software (question 5), respectively.

As for the helpfulness of the game in work on spreadsheet software, the positive response rate was relatively low (around 73%) compared to other questions. One possible reason could be that some students were not familiar with Excel spreadsheets or Excel functions. Other than these two, it can be concluded that the game is very helpful in understanding the topics related to cash-flow. In addition, the following are the students' actual comments on the game.

- *It's a good learning tool to actually see the money being transferred to where it's supposed to go and when.*

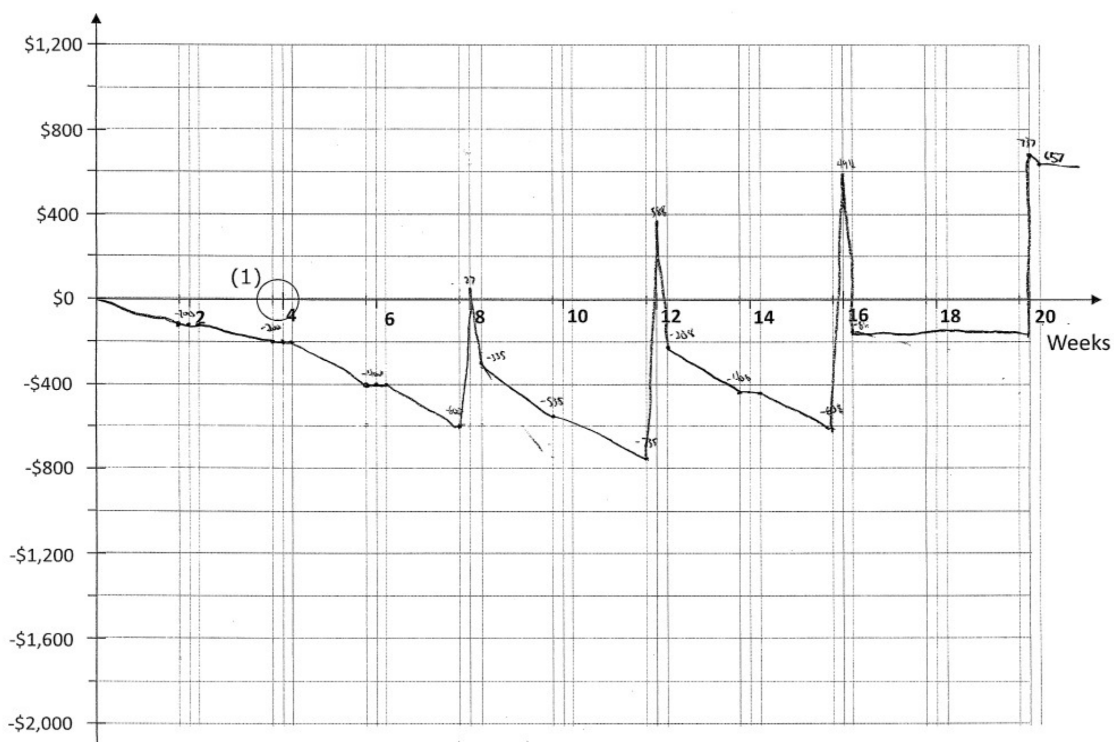

Figure 3. Example of the General Contractor's Balance Record

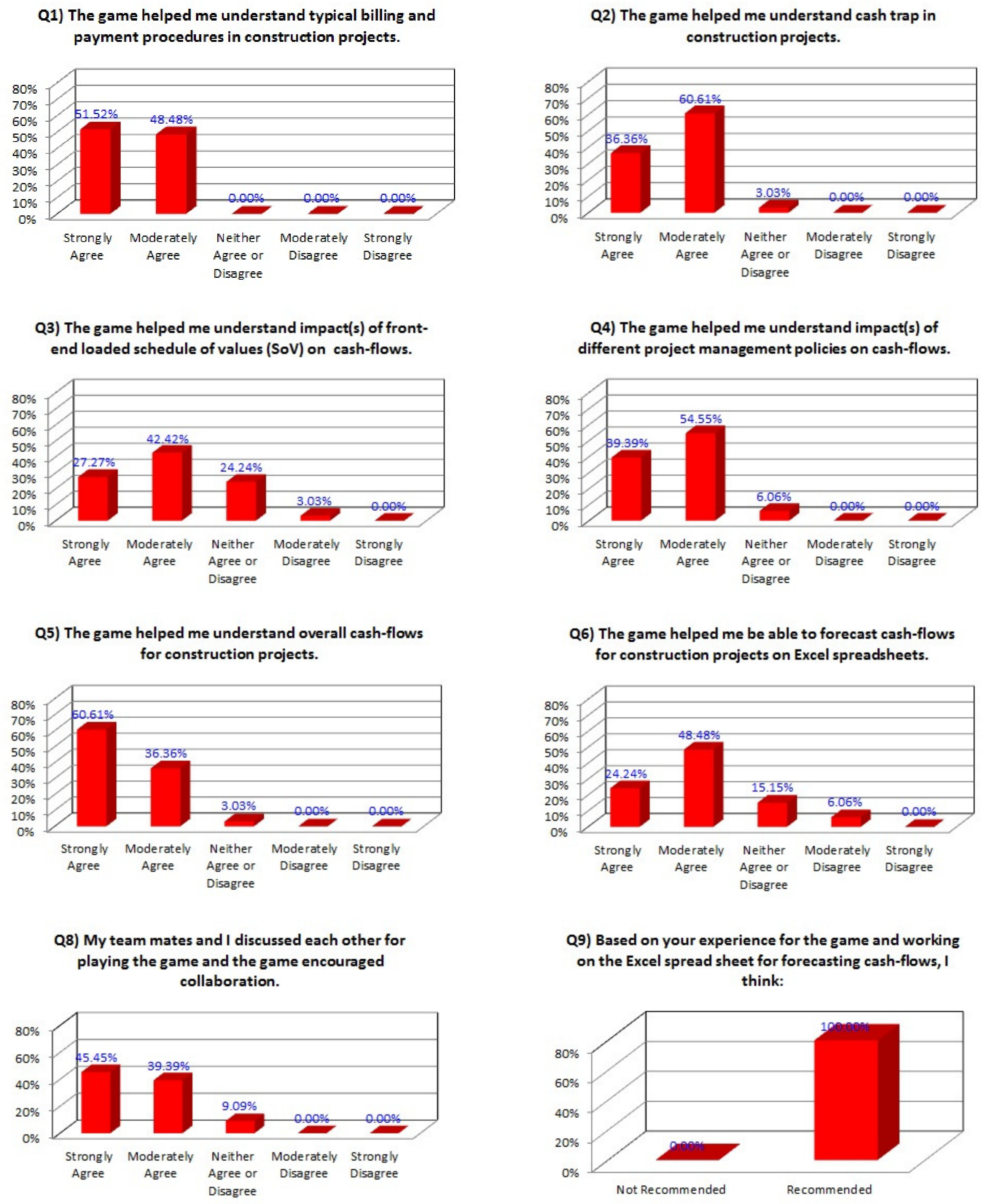

Figure 4. Results of the Questionnaire Survey

- *Great game thanks for coming up with it.*
- *It was fun and it made it easier to visualize the transactions.*
- *Helps with the physical understanding of cash flow.*
- *It's nice to do some hands-on work, and not always just learn from PowerPoint presentation.*
- *I liked the game, helped out a lot.*

This result cannot be a valid assessment of the efficacy of the game in teaching and learning, but it can prove that the game is applicable in teaching how to forecast construction cash-flows. Also, as mentioned in the students' comments, the game is a hands-on activity that is more interesting than a lecture. Therefore, it can motivate the students in quantitative cash-flow analysis on an Excel spreadsheet.

Conclusions and Discussion

Understanding features of cash-flow and prediction of cash-flow in construction projects are very important to construction companies. However, due to the combined impacts of multiple factors on cash-flow, many students in a CM program had a difficult time forecasting cash-flow. To help the students with forecasting cash-flow, the Cash-flow Simulation game was developed. The Cash-flow Simulation Game is to simply simulate transaction of cash as well as resources to help students visualize the actual transfer of cash in construction projects. In addition to the visualization of cash transfer, the students can easily determine the minimum balance of the general contractor (or the maximum amount of cash to be borrowed) from the game without complicated calculations. Furthermore, impacts of different managerial policies with regards to payment timing, schedule of values and amount of work to be subcontracted on cash-flow can be easily recognized from multiple rounds of the game.

The applicability of the Cash-flow Simulation Game was evaluated by a questionnaire survey. Based on the students' perceptions, it was concluded that the game helps students understand the features of cash-flow in construction projects and impacts of different policies on cash-flow. Also, it was determined that the game can facilitate collaboration between students and encourage active learning.

The game is helpful in teaching how to forecast cash-flow in construction projects, but it is not recommended that the game replace more formal approaches such as quantitative cash-flow analysis on an Excel spreadsheet; instead, the game should complement these approaches [17]. And though it was concluded that the game is helpful to student learning, the authors plan to perform a future study on the efficacy of the game in teaching and learning with objective data such as test results. This future research will enhance the reliability of the game for teaching and learning.

References

[1] Surety Information Office (SIO), Why Do Contractors Fail?, [www document], URL http://www.sio.org/index.htm , visited on Sep. 20, 2011

[2] Halpin, D. W. & B. A. Senior (2009). *Financial Management and Accounting: Fundamentals for Construction.* Hoboken, New Jersey, John Wiley & Sons, Inc.

[3] American Council for Construction Education (ACCE), Document 102: Manual for Preparation of the Self-evaluation Study, URL http://www.acce-hq.or, visited on Sep. 21, 2011.

[4] Shim, E. & S. Kim (2011). The Cash-flow Simulation Game: Introduction. 2011 Associated Schools of Construction (ASC) Region III Conference, Downers Grove, IL.

[5] Rafig, M. Y. & D. J. Easterbrook (2005). Using the Computer to Develop a Better Understanding in Teaching Structural Engineering Behavior to Undergraduates. *Journal of Computing in Civil Engineering, 19*(1).

[6] Lee, N. (2010). Design Issues and Implementation Strategies for Game and Simulation-based Learning in Construction Education. 46th Associated Schools of Construction (ASC) Annual International Conference, Boston, MA.

[7] Navon, R. (1995). Resource-based Model for Automatic Cash-flow Forecasting. *Construction Management and Economics, 13*(6).

[8] Peterson, S. J. (2009). *Construction Accounting and Financial Management*. Upper Saddle River, New Jersey, Pearson Education, Inc.

[9] Jackson, I. J. (1999). *Financial Management for Contractors.* Raleigh, NC, FMI Corporation.

[10] Clough, R. H., G. A. Sears, & S. K. Sears. (2000). *Construction Project Management*. New York, NY, John Wiley & Sons, Inc.

[11] Mincks, W. R. & H. Johnston (2011). *Construction Jobsite Management*. Clifton Park, NY, Delmar.

[12] Weber, E. (2009). Retention Lost in Lectures. *Web log comment in Brian Leaders and Learners*. Retrieved Dec. 18, 2011, from http://www.brainleadersandlearners.com/multiple-intelligences/retention-lost-in-lectures

[13] Kumar, R. & R. Lightner (2007). Games as an Interactive Classroom Technique: Perceptions of Corporate Trainers, College Instructors and Students. *International Journal of Teaching and Learning in Higher Education, 19*(1).

[14] Stein, J. & V. Gotts (2001). Analysis of Selected Learning Preferences of Construction Management Students. 37th Associated Schools of Construction (ASC) Annual International Conference, Denver, CO.
[15] Carns, D. W. & P. W. Plugge (2010). Creating and Utilizing a "Working Model Heat Pump" to Enhance Student Learning in a Construction Management Program. 46th Associated Schools of Construction (ASC) Annual International Conference, Boston, MA.
[16] AbouRizk, S. (1992). A Stochastic Bidding Game for Construction Management. 2nd Canadian Conference on Computing in Civil Engineering, Ottawa, Ontario.
[17] Nassar, K. (2002). Simulation Gaming in Construction: ER, The Equipment Replacement Game. *Journal of Construction Education, 7*(1).
[18] Halpin, D. & R. W. Woodhead (1973). *Constructo - A Heuristic Game for Construction Management.* Champaign, IL, University of Illinois Press.
[19] Dubziak, W. & C. Hendrickson (1988). A Negotiation Simulation Game. *Journal of Management in Engineering, 4*(2).
[20] Tommelein, I. D., D. R. Riley, & G. A. Howell (1999). Parade Game: Impact of Work Flow Variability on Trade Performance. *Journal of Construction Engineering and Management, 125*(5), 304-310.
[21] Beliveau, Y. (1991). Lego Bridge Simulation. *Company and Project Management Lectures*. Blacksburg, VA.
[22] Sacks, R., A. Esquenazi, & M. Goldin (2007). LEAPCON: Simulation of Lean Construction of High-Rise Apartment Buildings. *Journal of Computing in Civil Engineering, 133*(7).
[23] Mead, S. (2005). Using Poker to Teach Construction Risk Management. 41th Associated Schools of Construction (ASC) Annual International Conference, Cincinnati, Ohio.
[24] Park, M., S. L. Chan, & Y. Ingwale-Verma (2003). Three Success Factors for Simulation Based Construction Education. *Journal of Construction Education, 8*(2).
[25] Palmer, W. J., W. E. Coombs,& M. A. Smith (1994). *Construction Accounting & Financial Management*. New York, NY, McGraw-Hill, Inc.

Biographies

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PROCESS IMPROVEMENT THROUGH ESTABLISHED STANDARD WORK

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Abstract

In recent years, a line has been drawn that separates standard work from standardized work. Often considered foundational, standardization is about achieving consistency, or employing work measurement for flow optimization or task simplification. However, organizations that standardize may never realize the full potential of *lean*, which is process or system improvement. Standard work, in contrast, uses measurement to drive action. The contemporary view relies on visuals to distinguish normal from abnormal conditions, and to trigger problem resolution, or kaizen. While research overwhelmingly supports the learning of structured problem solving through a system, little is written on teaching the information flow in an educational or training setting. In this paper, a framework for connecting the flow of information for process improvement is demonstrated through simulation. In this study, current and past studies that contribute to the contemporary view of standard work were analyzed. Qualitative evaluation supports the use of simulation for teaching standard work in education, and the author suggests areas where further research is necessary.

Introduction and Background

Day [1] reiterates Taiichi Ohno's words, "…where there is no standard, there can be no kaizen". In early quality literature, standards commonly meant quotas, conformance, regulation or numerical measures that were acceptable or not acceptable [2]. Today, standards normally refer to an attribute, measurement, tolerance, target or requirement [3]. Continuous improvement relies on measuring against standards; so, if there are no standards, then there is no way to measure effectiveness or improvement.

Standards are achieved through standardization. The term 'standardize' is frequently associated with maintaining the first three S's—Sort, Set-in-order and Shine—in the 5S process [4-6]. Standardization commonly represents achieving a level of consistency or predictability by preventing variation in work tasks [7-9]. In many companies, standardized work is synonymous with SOP (standard operating procedures) [6], or the safest, easiest and most effective way currently known to perform an operation [10]. Standardized work is most often related to classical industrial engineering methods used for simplifying a product [8] or designing work activities. Time and resource measurements may be utilized to optimize production. Eliminating unnecessary steps, rearranging of operations, leveling, reviewing task sequence, matching production to demand, controlling work-in-process and putting into place mechanisms ensure stability in normal practice [10-12]. In systems, standardizing methods can prevent problems from reoccurring [13] and support adherence until a new improvement is made [14]. Shook [15] best described the dynamic role of standardized work and how this paves the path for continuous improvement by writing, "With standardized work, best practice is assured and the current best practice becomes the baseline for further improvement, or kaizen".

Standardization: Good for Change?

Without question, best practices should be captured and standardized; the absolute goal is kaizen, to identify muda, or waste, and continually develop processes. However, companies can regress if their standardized work fails to change [10]. A longitudinal study conducted on 119 organizations revealed that standardization can actually be problematic for change [9]. Huber et al. [9] note:

> Because standards are valued, and because organizational changes might lead to destandardization, change will more often be resisted in more standardized organizations. Consequently, it seems likely that organizational changes are less frequent in organizations characterized by greater standardization." (p. 239)

The analysis of findings in this study concluded that standardizing can lead to organizational efficiency, but can impede all types of change. Discussion with a CI manager at a Midwest company also supported this view. Often the problems encountered in production are lost after a temporary fix is applied. The manager's point is simple: Flow optimization or implementing measures that ensure that output matches what is planned, does not automatically help the process or system grow. High standardization, by itself, does not initiate the regular engagement in process improvement, or kaizen. The system must be designed so that when problems do surface, they are immediately captured, thoroughly documented, scheduled, solved and measured.

Standard versus Standardized Work

It is no surprise that standard work is underappreciated. Standard work and standardized work are often used interchangeably. While there is an abundant amount of literature on standards, standardization and standardized work, there is a clear absence of any universal *standard* definition for standard work. A brief search will reveal that the term standardized is often considered a poor translation from the Japanese meaning, and many do not distinguish standardized from standard. Mann [16], however, is one of the first to make a clear distinction, explaining that standard work is about management action taken to improve processes, and standardized work represents time elements for work including Takt, inventory amounts at stations and procedures. Duggan [17] contrasts standardized work and standard work by writing:

> Much has been written on establishing flow, standardized work and the visual factory. However, to grow the business, management needs to be freed from day-to-day operations. That happens by setting standard work for normal flow, making abnormal flow visual and creating standard work for abnormal flow so employees, not managers, can fix it. Management, then, can work on activities that will grow the business. (p. 29)

"Fix problems before they occur" is an integral result of developing and implementing standard work [16], [17].

Perhaps one of the more important contributions to standard work was captured in Costantino's [18] writing about the wood-processing company, Cedar Works. Standardized work methods such as work simplification, reducing non-value-added steps, balancing and developing work procedures were employed. Visual tracking charts that illustrated the performance of production with demand were essential in helping worker motivation, reinforcing change and identifying skill gaps. But it was through responding to undesirable conditions (wait times and line-stop conditions) that the latest model of standard work began to evolve. Since wait time resulted in variation, decision procedures were developed for line workers to restock areas, clean, assist neighbors and perform required maintenance. To reduce line stoppages, decision procedures were established to quickly deploy team leaders in the problem-resolution process in an effort to keep operations running. Developing If-Then actions eliminated downtime and eventually helped the company achieve a state of predictability and reliability.

Huntzinger [19] explained that problem solving is part of standard work and wrote, "Steady progress with continuous improvement depends on effectively incorporating improvements into Standard Work. Although 'ask why five times,' the informal version, subdues many problems, Plan-Do-Check-Act (PDCA, the Deming Circle) remains Toyota's fundamental problem-solving framework". In an LEI Lean Management Case Study, Plumbers Supply underwent a lean business transformation that involved developing standard work [20]. In the study, standard work was not just about developing procedures or checklists, but putting into place visual cues that indicate the presence of and subsequent action to rectify abnormal conditions.

Many lean practitioners differentiate standard work by implementing an improvement component or action. This is a noticeable separation between standard and standardized. Standardized work is almost universally associated with best practice, where improvements can still be made, while standard work is associated with seeing that the process is running as planned, problems are solved and processes are improved. Contemporary descriptions of standard work absorb and put into place kaizen activities, particularly closer to where work occurs. Although a review of the literature uncovered some differences in definitions and interpretation, closer examination did reveal shared themes in standards, standardized and standard work. Table 1 contains a simplified but collective comparison of standards, standardized work and standard work.

Standard Work for Kaizen

Stacks and Ulmer [7] explained that becoming a lean organization is about learning through root-cause problem solving. Many of the ideas of process improvement and preventing problems from reoccurring can be found in Deming's [2] writings. Deming described in simple language the Shewhart Plan-Do-Check-Act Cycle and how managers must take the lead to accomplish transformation. Scientific method models like PDCA and DMAIC are integral to continuous improvement. Schutta [21] adds, "Kaizen approaches involve using process thinking rather than functional thinking…The improvement process of kaizen uses Deming's plan-do-check-act approach to problem solving". PDCA is the structure for an improvement cycle that changes both standards and standardization [22].

Standard work is more than just job-instruction methodology or calculations. Standard work is about process or system improvement [10], [16], something that requires both awareness and understanding. Awareness is accomplished by identifying problems through visual control or detection of abnormal signals or misses. Andon or signal boards are effective in displaying to everyone, when and where a problem is occurring [7]. Pitch boards or tracking charts are

Table 1. Comparison of Standards, Standardized Work and Standard Work

	STANDARDS	STANDARDIZED WORK	STANDARD WORK
Sophistication level	Low	Intermediate	High
Meaning	● Target – Basis-desired condition	● Perform as planned - Expected ● Baseline for improvement	● Proactive -Taking action ● Analysis & Improvement
Function	● Support standardization ● Conformance ● Define normal (target)	● Enable/Support improvement ● Control - Simplify - Stabilize - Make routine and repeatable ● Become an efficient organization ● To achieve normal & recognize abnormal (departure from target)	● Process improvement action ● Development ● Become a learning organization ● Recognize & Act on abnormal
Primary Consideration	Desired performance	Current performance	Future performance
Question	What is the target?	Is the target reached? How can the target be reached?	Why wasn't the target reached? What went wrong? What is the remedy?
Elements	● Measurements ● Tolerances ● Regulations / Rules ● Ingredients ● Characteristics	● Work sequence or process steps ● Takt time calculation ● Inventory amounts (stock, SWIP) ● Layout planning	● Operator/Manager Action ● If-Then scenarios - Decision analysis - Contingencies ● Problem solving, Countermeasures ● Process/System adjustment
Format or Tools	Specifications Memos/Notes Illustrations Manuals Drawings Numerical	Standard operating procedures Operator instructions Balance or leveling charts Standard work process sheets Andon/Pitch boards, tracking charts Checklists/Audits	Pitch boards, tracking charts Decision diagrams Problem-Resolution Form Root-cause-analysis PDCA/DMAIC cycle Accomplishments board
Benefits	● Eliminate variation ● Consistency of output	● Eliminate variation ● Efficient work ● Stable operations ● Flow optimization ● Consistency of output	● Preventive - Eliminate variation ● Efficient decision making ● Change standardized work ● Stability - Prevent flow breakdowns ● Improve process/system

good for showing actual performance compared to expected performance. Awareness is also demonstrated through action to resolve the problem. Developing, selecting and implementing countermeasures are the PLAN and DO phases of the Deming cycle. However, implementing solutions to problems does not necessarily indicate that learning has taken place. Problems still can be solved using stop-gap techniques or temporary solutions that do not change standardized work. Such solutions do not result in process improvement, only a certainty that the organization is likely to encounter the problem again. PDCA involves system discipline, so learning takes place and mistakes are not repeated [15]. Understanding, or becoming a "learned" organization, requires follow-up to determine if the countermeasure was successful and subsequently taking some kind of action. If the countermeasure was successful, this should yield changes to either standards, standardized work or both. If the countermeasure was not successful, then the team should be sure the problem is correctly identified and, if so, then select an alternative countermeasure. Allen and Thomerson [23] reinforced the importance of change as problems are solved and wrote, "…the real aim of this process is for the operators to gain ownership of the standard work. Lean enables operators and gives them the skills to analyze abnormalities (e.g., quality issues, equipment downtime and overtime) and solve problems using plan-do-check-act/ adjust methods and statistical process control tools".

Standard work is the structure put in place to engage in kaizen, which is accomplished through the final two phases of the Deming cycle: CHECK and ACT. When processes or systems positively change, kaizen may result in changes to standards or standardized work. Figure 1 depicts Standard Work (leadership action) for problem resolution and process improvement using the Deming cycle. Leader standard work recognizes that standardized work will change as standards change.

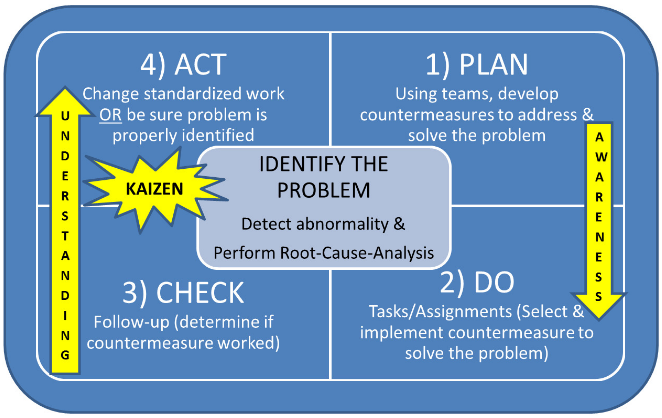


Figure 1. Deming Cycle for Problem Resolution & Process Improvement

Improvements should be connected to business performance; and having a mechanism in place to capture problems is critical. Strategy deployment is often conducted using a catchball approach that employs PDCA at operational, tactical and strategic levels [24]. Catchball refers to information sharing through the levels so that everyone understands the goals of the organization and becomes involved in problem solving for improvement. The decentralized method involves using team-based problem solving closer to where work occurs, promoting both horizontal and vertical integration. Measurements are recorded and dashboards are used to indicate performance metrics so that leadership can make informed decisions.

The power of standard work is found when the process or system changes and fundamental to standard work is the establishment of visuals to drive management decisions. Visual control is commonly described as making it possible for everyone to see whether the situation is right or wrong, or normal or abnormal [11]. Lean systems rely on visual indicators or signals that reflect standards to generate action. Dennis [10] describes three characteristics of standards and how they support visual management: "A standard is a clear image of a desired condition. Standards make abnormalities immediately obvious so that corrective action can be taken. A good standard is simple, clear, and visual".

Lean Simulation

For years, simulations have been used in training and education for replicating workplace practices and teaching lean flow techniques. The learning benefits and power of using simulations, particularly the mechanics of lean, have been well-documented. Participants get hands-on exposure and observation of process improvement [25-27]. Simulations can be very effective for illustrating visual control, understanding value streams, realizing the importance of reducing defects and learning how charts track performance. One simulation model demonstrated a method for engaging students in an improvement cycle using Lego-constructed airplanes [27]. Simulations have often been used to test scenarios for error and throughput. In a clinical setting, simulation has been used to examine the impact of lean practices on resource utilization, distance traveled, wait time and patient flow [28].

Problem of Opportunity

While simulations have been essential to teaching fundamental lean flow concepts, the exercises do not teach the development of, in the contemporary sense, standard work. Mcleod [25] explained that signal systems employed to illustrate process status can be challenging and difficult to explain in educational environments. Without structure, there can be disconnect in tying a visual signal of an abnormality to employing action that improves the process. Linking process performance to action presents a problem of opportunity, particularly in simulation development.

Methodology

Simulation was selected as the vehicle for delivering standard work instruction to 24 students in a junior-level, Engineering Technology Cost Reduction class during the fall, 2012, semester. Six students had some form of workforce experience. College-leavers quickly find that lean is not only being applied in manufacturing, but also office, healthcare, finance, agriculture, construction and distribution. Because most simulation participants did not have prior work experience, a general discussion of potential problems (abnormalities) in both production and service industries was necessary. Countermeasures, or problem-solving measures, were also discussed. Table 2 contains a condensed list of some abnormalities and countermeasures that can take place in a variety of fields.

Visual control techniques and their purpose are usually new for most students, even for those who have work experience. As a primer, participants were given detailed instruction on visual control techniques as used in industry. More than 100 pictorial examples (see Figures 2 and 3) of visual control were used to familiarize students with the value of organization, status and signaling. Supermarkets, FIFO lanes and Red-Amber-Green (RAG) color coding (status indicators) were presented to reinforce the simulation experience. Figure 2 illustrates First-In-First-Out (FIFO) control and sequence of repair work to be completed for plastic injection molding operations. Clipboards serve as kanbans, and the first repairs to be made are outlined using red boxes for the two FIFO lanes. In Figure 3, Andon lights use red and green to indicate process status differentiating normal from abnormal conditions.

Table 2. Forms of Abnormalities and Countermeasures

ABNORMALITIES
• Failure/Non-conformance in information, material, product, people, machine, process, system (cosmetic, functional, procedural, policy, design) • Amount/Level (conditions, information, material, people, orders, knowledge) • Schedule (interruptions, time delay, sequence) • Omission (missing information, steps, data, knowledge, parts, tools, equipment, personnel) • Safety (injury producing, environmental) • Geographical (location, placement, or delivery error)
COUNTERMEASURES
• Good communication (visuals, pictures, clear instructions) • Decision Logic (if-then scenarios) • Flow strategies (layout, balancing, sequencing, combining, leveling) • Quality checks or audits • Design changes (product, process, system) • Education (training, cross-training) • System approaches (DMAIC, PDCA)

Familiarity of basic flow fundamentals was necessary. The class had completed simulations that involved standardizing using Takt calculations, leveling and combining operations. Instruction also involved Value Stream Management and pull signaling with kanbans. Up to this point, all scenarios illustrated the mechanical side of lean, not the systematic structure and information flow for making process improvements. Before engaging in simulation, students needed to understand the purpose of the exercise. The following eight questions were displayed on a white board:

1. What is normal? (the target/standard)
2. How is an abnormal condition recognized?
3. How are leaders informed about the abnormal condition?
4. How is the abnormal condition documented?
5. How is action for a resolution process triggered?
6. How is the abnormality resolved?
7. What prevents the abnormality from reoccurring?
8. How is performance of resolving abnormalities measured?

Figure 2. FIFO Lanes Used to Control Work Sequence

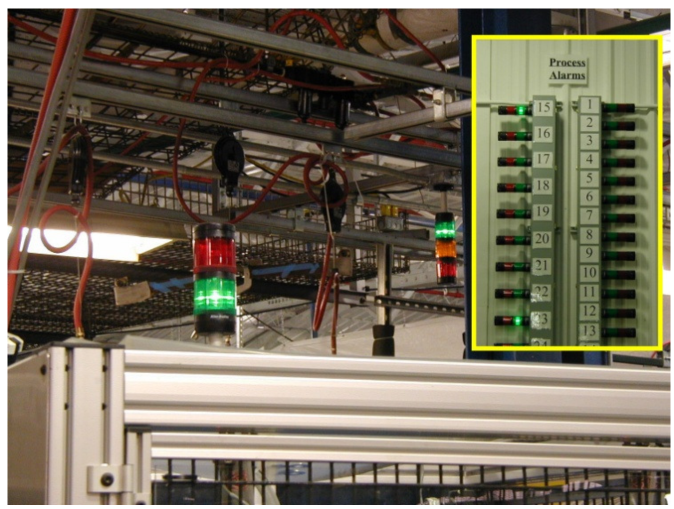


Figure 3. Andon Lights Used to Distinguish Normal from Abnormal in Processes

These questions were used to help students make the information connection necessary to show that lean is more than just about material flow; lean is also about flowing information to rapidly solve problems. The questions were to be addressed through standard work development and were revisited throughout the exercise.

The Simulation

It is important to note that the simulation chosen was not as important as the overall purpose for improving the process. A variety of simulations can be easily modified to incorporate standard work development. Due to time and spatial constraints of a university setting, the simulation chosen for teaching standard work was the assembly of a mechanical pencil.

Figure 4 depicts the initial architecture of the simulation, which involves four assembly operations and a final test operation. The exercise is activated by a pull signal from a finished-goods supermarket that contains three colors of the finished product. When an order of a particular color is made, a kanban signal is sent to Operation 3, where colored sleeves are assembled to the single Work-in-Process unit. The product is then transferred to a FIFO lane where the tips are assembled at Operation 4 and the product is tested at Operation 5 before being placed in the supermarket. The simulation uses pull for Operations 1 and 2, but in the form of visual control using designated spaces, thereby eliminating kanbans. WIP is held to one single subassembly unit between the first three operations.

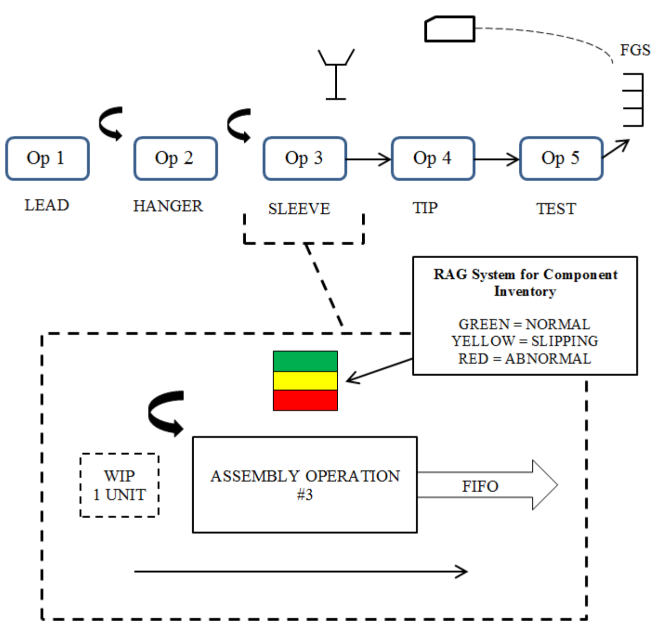


Figure 4. Simulation using Visual Control for WIP and Supply Chain Inventory

Several walk-throughs of the simulation were conducted to familiarize students with the mechanics of the assembly at the stations and flow of the material throughout the simulation. For instance, Operation 2 could not initiate assembly operations until the downstream customer, Operation 3, pulled the work-in-process unit. This simulation is comparable to many other single-piece flow simulations used in training, and provides a good starting point (current state) for making improvements. The mechanics of lean have been well-documented in the literature. Calculating Takt, balancing, changing sequence, combining and reacting to demand shifts are integral to future states of this simulation. However, these are omitted since the focus of this article is information flow and actions to resolve problems.

PLAN: Procedure Development for Normal and Abnormal

Each of the assembly and testing operations needed normal condition procedures. Students were divided into teams and assigned to a station. One team member was assigned as the team leader. Since participants had never had experience developing procedures, instructor guidance was given. Hernandez [29] outlines several points when developing systems and procedures:

1. Procedures should be concise.
2. Procedures should be meaningful to those who will use them.
3. Procedures should be dynamic and change with feedback.

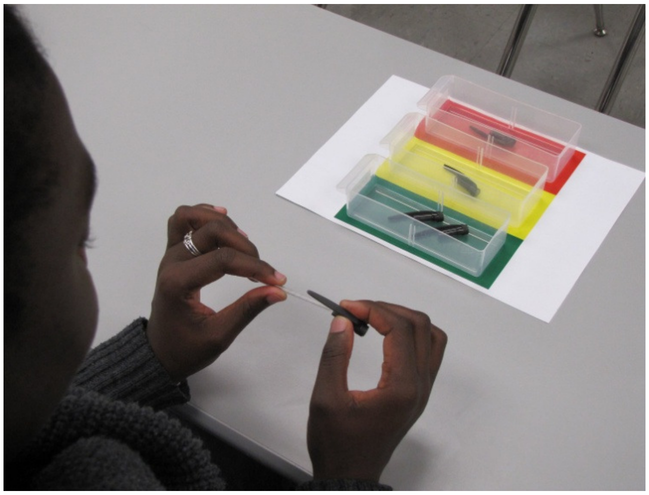
General procedures were reduced to 3-4 concise steps for each operation. Although essential in real-world applications, time limits made implementing visuals impossible.

The phase also involved developing operator standard work for the supply chain component inventory levels, or the parts to be added to the subassembly. Teams were encouraged to review the types of abnormalities provided in Table 2. To further guide students, the following guidelines were given:

1. Indicate the condition, situation or status.
2. Use IF-THEN thinking. Anticipate problems that can occur and what actions operators may take.
3. Make the operator-to-leader connection.
4. Generate a signal that drives leader action and follow-up.

Students were given the goal of developing procedures that drive action. Each assembly station was given a Red-Amber-Green sheet without documentation and a marker for writing. The sheet represented a buffer for in-process supplier inventory. Green color-coding represented normal component inventory, yellow represented slipping and red represented a critically low inventory level. Figure 5 shows the second assembly operation with color-coding for supply inventory.

Figure 5. Assembly Operation 2 with RAG System for Supply Inventory



A comprehensive approach was taken to show the application of all RAG conditions and how they can play a role in action. It is important to note that yellow conditions may or may not be necessary; many industrial applications simply have two conditions, green for normal and red for abnormal. Figure 6 illustrates a recreated example of student-generated standard work for component inventory at Operation 2, and actions to be taken if an abnormal condition becomes present. When an operator picks inventory from the yellow zone, the supply of parts necessary for assembly gets low, so the operator has to stop and record the event before resuming assembly. Recording the yellow condition gives the team leader a chance to respond and address the issue before reaching critical status. If the condition worsens, where the operator draws from the red zone, inventory becomes critically low and standard work tells the operator to halt assembly, record the problem and immediately notify the team leader. Similar procedures were developed at other stations.

QUANTITY = 3 UNITS	INVENTORY GOOD → 1) ASSEMBLE AS PLANNED
QUANTITY = 1 UNIT	INVENTORY GETTING LOW → 1) STOP & RECORD SLIPPING 2) FILL OUT PROBLEM FORM 3) RESUME ASSEMBLING
QUANTITY = 1 UNIT	INVENTORY CRITICALLY LOW → 1) STOP ASSEMBLING 2) NOTIFY TL IMMEDIATELY

Figure 6. Student-Developed Operator Standard Work for Normal and Abnormal Conditions in Supply Inventory

IMPLEMENT: Test Normal

Once the first phase of standard work was drafted, one member of each team was tasked with performing the operation. Procedures developed by the groups were shared with the entire class before testing. One team leader was selected and assigned to ensure that the five stations were running normally, or at least as planned, in the simulation. So, for the purpose of demonstration, six participants were engaged in the simulation, while the remainder of the class watched. Flow was initiated by the customer pulling from the finished-goods supermarket at the end of the five-process simulation. Initially, the simulation ran smoothly. Station restocking was based on a trigger signal from shipping; this was an important system characteristic because it did not allow for stations to cover up quality issues that might otherwise be hidden by a local pull signal. Green-zone inventory for assembly stations was replenished for every three products shipped from the finished-goods supermarket.

CHECK: Recognizing Abnormal

For students to engage in an improvement action, an abnormality must occur. Participants should be able to react to problems involving quality, time and shortages. In practice, various disruptions are presented in order to determine the effectiveness of standardized operating procedures and standard work for actions at each station. For instance, simulation disruptions involve delays, demand shifts and quality issues. This exercise offered endless possibilities for testing the system. The following scenario demonstrates a supplier quality abnormality in an effort to test student-generated standard work for the component inventory.

After several successful rounds, new inventory was replenished for each assembly station (as necessary). In the next cycle, a product was shipped from the finished goods supermarket, which sent a kanban signal to Operation 3. Operation 3 pulled the WIP subassembly from Operation 2, as expected. However, Operation 2 discovered a damaged component in the normal (green) zone in the attempt to assemble and replenish the WIP for Operation 3. Because non-conforming parts cannot be assembled properly, Operation 2 pulled again from the supply component inventory. Normal component inventory eventually became exhausted, and the operator began to tap into the yellow-zone inventory during the third activation (1 cycle prior to replenishment). Students immediately visualized the presence of an abnormal condition at Operation 2. Obviously, this was going to have a ripple effect downstream to Operation 3 for the next product shipped from the finished-goods supermarket. There was the threat that Operation 2 could not complete conforming work-in-process inventory ready for Operation

3. This situation quickly sensitized students of the importance of supply chain stability, and it was at this point that the effectiveness of local operator standard work was tested.

An essential part of this standard work phase was documenting the abnormal condition, no matter how small or large. It was through data collection that trends or patterns presented themselves. Now that an abnormality had occurred, a visual had to be registered so that the team leader would notice and a remedy, either short-term, long-term or both, could be applied. Since Operator 2 had tapped into the yellow zone (low inventory), standard work required that the assembly halt and the problem be recorded. To record the problem, a tracking chart was used. Charts can use numerical values or RAG color coding within a time interval or track expected versus actual performance in scheduled production (as in a Pitch or Andon board). Figure 7 illustrates a simple magnetic tracking chart that indicates normal or abnormal for a work time interval.

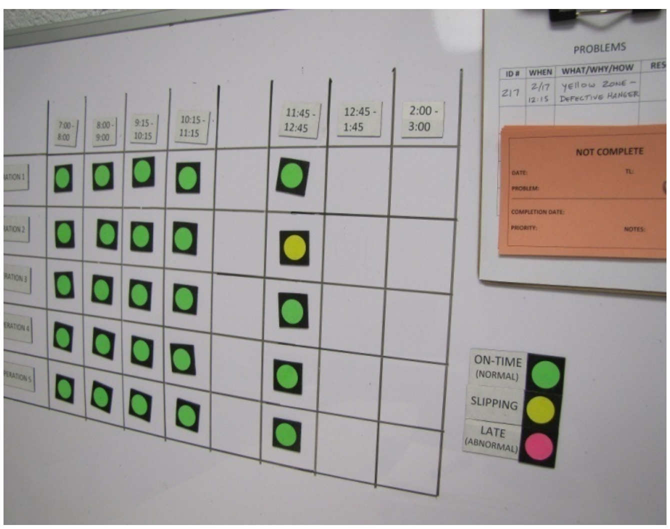


Figure 7. Tracking Chart for Normal and Abnormal

After recording the yellow or slipping condition in the appropriate time interval, the operator filled out necessary information on the Problem Form, as stipulated by standard work. Attached to each Problem Form was a red kanban to be filled out and used for task accountability and tracking. Operator 2 then returned and resumed assembly, as prescribed in local standard work. In this test, student-generated operator standard work was successful. If the problem was not resolved in a timely fashion, the following pull signal from the finished-goods supermarket to Operation 3 would result in a red dot, or imminent shutdown, because there was no WIP from Operation 2.

ACT: Leadership Action

In another scenario, a problem was captured and documented by the visual tracking chart and a Problem Form. The visual tracking chart can be used in conjunction with an accountability board. A task accountability board helps schedule problem solving, whereby leaders are responsible for follow-up resolutions to the problems discovered by operators. Documentation can be directly applied or transferred from the Problem Description Form to cards or kanbans, which are placed on the accountability task board. This allows everyone to see the status of improvements.

Figure 8 illustrates a task-board format for leadership action. This is easily color coded, where green represents "problem solved" and red indicates "resolution still needed." Boards do not require much structure. In the simulation, a chart was made using a whiteboard with 3"x5" index cards. Index cards are green on one side and pink on the other and can be easily taped to the whiteboard. Other formats involve green-pink sticky notes, magnetic flip cards or just using red and green markers. The kanban format allows for project prioritization to more easily take place. Task-board information can vary. In this simulation, information on the abnormality was kept to a minimum, indicating the date/time of occurrence, team leader and description of the problem. Expected completion date and priority would be filled out by the team leader. In this way, management can verify the status of solving the problem.

DAILY KAIZEN (PROBLEM & RESOLUTION)				
TEAM LEADER	2/14	2/15	2/16	2/17
John (area 1)				
Margret (area 2)				
Sally (area 3)				
Brad (area 4)				

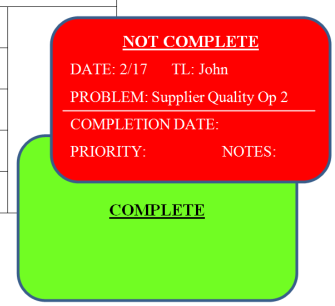


Figure 8. Task Board Format for Leadership Action

It is at this point that leader standard work is reviewed. Follow-up of an abnormal condition requires leadership action. Leader standard work may occur at timed intervals or at random. The visual tracking board makes it easy for the team leader to perform a quick scan in order to determine how the system is doing. Because the possibility exists that the leader is working on solving another problem, frequent, scheduled checking of the tracking board is helpful in preventing a shut-down situation. Standard work must define the how frequent the board is to be reviewed, and if-then scenarios should guide the action to be taken. Mann [16] explains:

> …leaders must quickly perceive the series of step-by-step actions to attack a flow interrupter or develop an improvement. This skill, the ability to see an implicit work-breakdown structure, is necessary to make appropriate one-step-at-a-time task assignments that cumulatively respond to the interruption or opportunity. Follow-up on these task assignments is straightforward with the visual daily task board on which assignments are posted. (p.77)

In the simulation, the tracking board displayed and documented a supply chain disruption for Operation 2. Table 3 showed leader standard work developed as a class. Following standard work, the team leader immediately recognized the yellow condition, retrieved the Problem Form with kanban and met with Operator 2. Once the facts were determined, new parts were delivered to Operation 2 and the kanban was placed on the accountability task board to look into identifying and solving the problem.

Table 3. Leader Standard Work

1) CHECK TRACKING CHART EVERY 15 MINUTES.
2) IF ABNOMALITY PRESENT, MEET WITH OPERATOR TO ASSESS SITUATION.
3) DOCUMENT ABNORMAL CONDITION USING PROBLEM FORM.
4) IS PROBLEM CRITICAL?
   YES → CONTACT MANAGEMENT
   NO → PROCEED TO STEP #5
5) CAN PROBLEM BE FIXED IMMEDIATELY?
   YES → FIX PROBLEM & SUBMIT PROBLEM FORM TO MANAGEMENT
   NO → FILL OUT KANBAN AND PLACE ON TASK BOARD
6) COMPLETE TASK BOARD ASSIGNMENTS

It is at this point that students made a connection between the abnormal signal and the problem-solving action through leader standard work. Similar to developing operator standard work, students had to account for how leaders were to follow through with action. Figure 9 illustrates leader standard work for the task board developed by using a logic diagram.

Students were again placed in their respective groups and the team leaders were charged with following leader standard work and addressing the kanban on the task board. It was through the PDCA process that changes to standards and/or standardized work would be made. For this simulation, the root cause was determined to be a non-conformance delivery by the supplier.

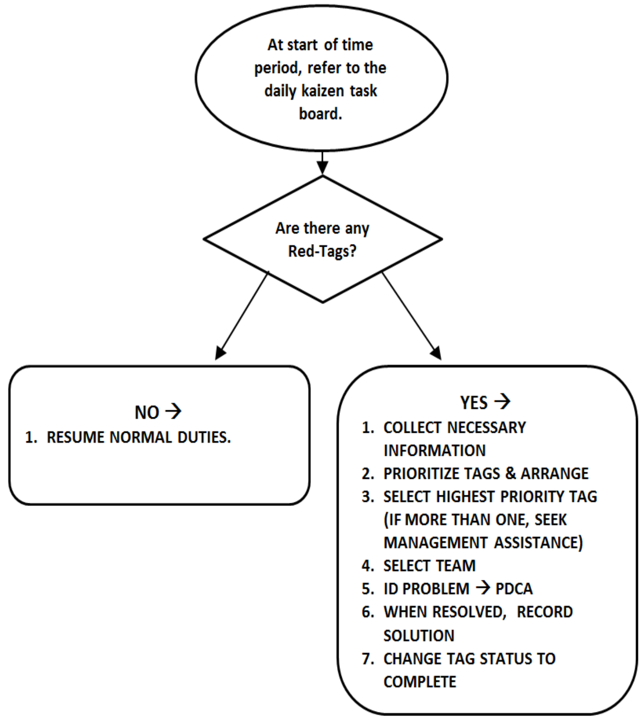


Figure 9. Leader Standard Work to Initiate Problem Resolution

Student teams were charged with resolving the problem and results varied as expected. Standardized work should not only make clear what is to be done, but also what is not to be done. Students were quick to realize that while they had developed assembly procedures for each operation, they failed to initially develop standard work to resolve problems. All students felt this was an indicator of a system shortcoming. In the example detailed, Operator 2 pulled from the yellow-zone inventory. A defective product itself is a visual indicator, and some believed this should not be tolerated. Accepting poor quality was not a good standard and should automatically be considered a red-tag condition, rather than waiting for inventory levels to trigger operator action. The class agreed that quality disruptions required immediate attention, since these could compromise the ability to satisfy internal and external customers. This logic changed the standard and resulted in a standardized countermeasure: If a defective part is encountered, then halt assembly and notify the team leader. Other suggestions indicated that component inventory amounts may need adjusting until the reliability of the supplier is improved. One team suggested having a quality check before delivery to the operation, or requiring the supplier to perform an inspection. Some responses involved seeking a new supplier altogether. All of these adjustments to the system or process were appropriate. Review of handling and design would also have been appropriate.

When a problem is resolved through PDCA, then a red-status visual on the task board can be changed to green. The Problem Form is updated to indicate countermeasure implementation and can then be sent to management. From here, a metric board can be used to analyze problem solving even further.

Evaluation

Generally speaking, students enjoy educational experiences when they are engaged in activities, especially simulations. Qualitative feedback from simulation participants included:

"Keep using the simulations - makes the class go by fast."
"Lectures are good, but the simulations are better for showing how things work."
"I can't wait to see this practiced in my job."
"My company applies kaizen without any direction. Now I understand how visuals and good instructions can lead to change."
"Information has flow."
"Lean is more than I first thought."

In this exercise, students collaboratively engaged in a closed-loop improvement cycle where visual mechanisms initiated front-line decisions. This simulation helped make the connection between an event that is visually captured and problem solving, demonstrating that lean tools are geared toward process improvement.

Conclusion

Standardization is about performance done right the first time, whereas standard work is about making adjustments to the process or system. The example just presented made system adjustments to an abnormality and standardized the improvement within the system in an effort to eliminate future supplier quality problems and to diminish rework. Where standardized work is commonly characterized by procedures to ensure uniformity or industrial engineering techniques for flow stability, a contemporary meaning of standard work incorporates visuals to drive the process improvement cycle. This movement or shift may be in part because more fields have adopted lean which, too, has fueled new ideas for advancement and growth.

There is still much opportunity for further study. For instance, analysis on standard work versus standardized work can be completed through industrial surveys or interviews. Researching the various techniques for teaching standard work (in a problem-resolution sense) is also very reasonable. It stands to reason that if standard work is one of the highest leverage tools in lean, then this should be taught in university programs. While much has been written on the importance of teaching the mechanical side of simulations, little has been demonstrated on how to implement information flow for process improvement in an educational or training environment. The writings of McManus et al. [27] suggest that many research opportunities exist in designing simulations to address this need. While the simplified example presented in this paper illustrates standard work for a supply chain disturbance, the same practices can be used for finished-goods inventories, cross training employees, monitoring flow of in-process work using Pitch boards or Heijunka boxes, completing business information requests and numerous other areas in a system.

Some organizations measure to the standard, while others use measurement to drive process change. Visual thresholds supported with decision logic can expose system weaknesses. It seems logical that all companies will benefit by having a blend of standardized work—that optimizes flow—and standard work—which uses a structured approach—for action to improve processes when abnormalities arise. Without this integration, follow-up may suffer and many if not most employees will be exempt from regular improvement of processes. Through study and application, it becomes evident that both standardized work and standard work evolve with system maturity. However, no matter what level of sophistication, recognizing, developing, implementing, testing and acting remain critical factors for the continued advancement of any system.

References

[1] Day, J. C. (1998). Learning about lean systems at Freudenberg-NOK: Where continuous improvement is a way of life. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 178-198). New York: Productivity Press.

[2] Deming, W. E. *Out of the crisis.* Cambridge, Massachusetts: MIT Press.

[3] Schroeder, R. G. (2008). *Operations management: Contemporary concepts and cases.* New York: McGraw-Hill Irwin.

[4] Feld, W. M. (2001). *Lean manufacturing: Tools, techniques, and how to use them.* New York: CRC Press.

[5] *Standard work for the shop floor.* (2002). New York: Productivity Press.

[6] Summers, D. (2011). *Lean six sigma: Process improvement tools and techniques.* Upper Saddle River, New Jersey: Prentice Hall.

[7] Stacks, C. & Ulmer, J. M. (2009). Applied lean thinking: general usage principles. *The Technology Interface Journal, 9* (2).

[8] Martin, J. W. (2009). *Lean six sigma for the office.* Boca Raton, FL: CRC Press.

[9] Huber, G. P., Sutcliffe, K. M., Miller, C. C., & Glick, W. H. (1993). Understanding and predicting organizational change. In Huber, G. P. & Glick, W. H. (Eds.), *Organizational change and redesign: Ideas and insights for improving performance* (pp. 215-265). New York: Oxford University Press.

[10] Dennis, P. (2002). *Lean production simplified: a plain language guide to the world's most powerful production system.* New York: Productivity Press.

[11] Hirano, H. & Black, J. T. (1988). *JIT factory revolution: A pictorial guide to factory design of the future.* Cambridge, Massachusetts: Productivity Press.

[12] Kosaka, G., Kishida, M., Silva, A. H., & Guerra, E. (n.d.). *Implementing standardized work at ThyssenKrupp in Brazil.* Retrieved January 11, 2013, from http://www.lean.org/admin/km/documents/6d8be412-c448-425d-b852-86962a16f736-SW_TK_English.pdf

[13] Harry, M. and Schroeder, R., (2000), *Six sigma: The breakthrough management strategy revolutionizing the world's top corporations.* New York: Doubleday.

[14] *Pull production for the shop floor.* (2002). New York: Productivity Press.

[15] Shook, J. Y. (1998). Bringing the Toyota production system to the United States: A personal perspective. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 40-69). New York: Productivity Press.

[16] Mann, D. (2005). *Creating a lean culture: Tools to sustain lean conversions.* New York: Productivity Press.

[17] Duggan, K. (2012). Flowing toward business growth. *Industrial Management, 54*(5), 28-30.

[18] Costantino, B. (1998). Cedar works: Making the transition to lean. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 302-387). New York: Productivity Press.

[19] Huntzinger, J. (2006). Why standard work is not standard: Training Within Industry provides an answer. *Target, 22*(4), 7-13.

[20] Drickhamer, D. (2009). *Lean in distribution: Go to where the action is!* Retrieved January 3, 2013, from http://www.lean.org/common/display/?o=2179.

[21] Schutta, J. T. (2006). *Business performance through lean six sigma: Linking the knowledge worker, the twelve pillars, and Baldrige.* Milwaukee, WI: Quality Press.

[22] Harrington, H. J. & Lomax, K. C. (2000). *Performance improvement methods: Fighting the war on waste.* New York: MaGraw-Hill.

[23] Allen, J. & Thomerson, G. (2008). Better way in vogue: Lean takes to the catwalk in the garment industry. *Industrial Engineer, 40*(11), 45-50.

[24] Bell, S. & Orzen, M. A. (2011). *Lean IT: Enabling and sustaining your lean transformation.* New York: CRC Press.

[25] Mcleod, A. (2009). Conceptual development of an introductory lean manufacturing course for freshmen and sophomore level students in industrial technology. *The Technology Interface Journal, 10*(4).

[26] Stier, K. (2003). Teaching lean manufacturing concepts through project-based learning and simulation. *Journal of Industrial Technology, 19*(4), 2-6.

[27] McManus, H. L., Rebentisch, E., Murman, E. M., & Stanke, A. (2007). Teaching lean thinking principles through hands-on simulations. *Proceedings of the 3rd International CDIO Conference.* MIT: Cambridge, Massachusetts.

[28] Farahmand, K., Karim, R., Srinivasan, R., Sajjadi, R., & Fisher, L. (2011). Lean Enterprise principles applied to healthcare. *International Journal of Engineering Research and Innovation, 3*(2).

[29] Hernandez, A. (1989). *Just-in-Time manufacturing: A practical approach.* Englewood Cliffs, New Jersey: Prentice Hall.

Biography

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TRADITIONAL, BLENDED, AND ONLINE TEACHING OF AN ELECTRICAL MACHINERY COURSE IN AN ELECTRICAL ENGINEERING TECHNOLOGY PROGRAM

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Abstract

With increasing emphasis on student learning outcomes and assessment, educators constantly seek ways to effectively integrate theory and hands-on practices in inventive course design methodologies. Critics of engineering education argue that educational programs focus too much on the transmittal of information through static lecture-discussion formats and routine use of outdated laboratory exercises. On the other hand, active learning, the learning that involves hands-on experience, significantly improves student comprehension and proficiency. It is clear that understanding and retention are greatly enhanced when students engage in active learning. While theoretical knowledge remains a fundamental component of any comprehension process, the underpinnings of proficiency development seem to increase best through active learning practices. What remains less clear is the "gold standard" for pedagogical approaches that combine theory and hands-on learning.

The Electrical Engineering Technology (EET) program in the School of Technology (SoT) at Michigan Tech is constantly revamping the curriculum to meet the expectations of industry by supplying qualified technicians and technologists who have extensive hands-on experience. To further enhance and make the curriculum model more flexible, all programs across the School of Technology are developing and offering online courses in multiple disciplines. In this paper, authors emphasize the development and implementation of three models of an Electrical Machinery (EM) course offering. The traditional way of teaching of an EM course for EET and Mechanical Engineering Technology (MET) majors has already been offered several times, allowing the authors to collect data on student comprehension. The goal of a blended approach is to join the best aspects of both face-to-face and online instruction: classroom time can be used to engage students in advanced learning experiences, while the online portion of the course can provide students with content at any time of the day allowing for an increase in scheduling flexibility for students. A 70/30 hybrid of traditional and online versions of the EM course has been offered three times, which in turn has triggered the development of fully online and fully blended versions of this course. The online EM course was offered in the summer of 2012 for a class of four students, and the blended version of the course was conducted in the fall semester of 2012 for a class of 45 students.

In this paper, the authors present the structural details of all course models, including the theoretical topics and experimental exercises, the technology being used for the online materials development, implementation of the assessment tools to evaluate student progress, and student perception of all educational models.

Introduction

With a growing emphasis on student learning outcomes and assessment, faculty and educators constantly seek ways to integrate theory and research in innovative course design methodologies [1-5]. Critics of engineering education argue that educational programs focus too much on the transmittal of information through static lecture-discussion formats and routine use of outdated laboratory exercises [6], [7]. This educational approach often results in graduates who do not have a full range of employable skills, such as the ability to apply knowledge skillfully to problems, communicate effectively, work as members of a team and engage in lifelong learning. As a result, engineers and engineering technologists often enter the workforce inadequately prepared to adapt to the complex and ever-changing demands of the high-tech workplace [8]. Research [9-11] shows that active learning, learning that involves hands-on experience, significantly improves student comprehension and proficiency. In a study by van and Spencer [12] where researchers compared learning outcomes in a management class, taught using lecture-based methods versus active learning methods, an improvement of one standard deviation was demonstrated with regard to long-term memory and use of concepts over time for the active learning group [8]. Similarly, in a study of over 6,000 participants enrolled in an introductory physics class [13], students who engaged in active learning scored two standard deviations higher on measures of conceptual understanding of Newtonian mechanics than did students in a traditional lecture-based course.

Recent studies reinforce the importance of blended learning due to its impact on students. Students also recognized the value of the blended course delivery. An Eduventures survey of 20,000 adult students found that only 19% of responders were enrolled in blended courses [14]. However, 33% of all respondents cited it as their preferred format [15]. This preference suggests that student demand for blended and hybrid courses exceeds the number offered by institutions nowadays. In another study [14], the aggregated results from surveys on the effectiveness of blended learning were presented. The survey was issued at 17 institutions during the 2010 academic year [14]. A total of 1,746 students in the United States and the United Kingdom participated in the survey. According to the key demographic data presented in the study, only 5% of the participants were from engineering and 4% from computer science. The students' responses on the survey, regarding the advantages of blended learning compared to traditional teaching methodologies, was positively overwhelming.

It is clear from these studies that understanding and retention are greatly enhanced when students engage in active learning. While theoretical knowledge remains a fundamental component of any comprehension process, the underpinnings of proficiency development seem to flourish best through active learning practices [8], [13-15]. What remains less clear is the "gold standard" for pedagogical approaches that combine theory, hands-on and active learning approaches in various fields of engineering. The question that needs to be addressed is whether or not any course in engineering can be converted to its online and/or blended versions to ensure effective student comprehension of the subject taught.

Traditional, Online, or Blended Learning

The rapidly evolving technological world requires engineering skills be up-to-date and relevant. This applies to industry-employed workers as well as students pursuing a college degree. To keep up with the rapid developments in technology, industry representatives need to constantly update their knowledge base. On the other hand, the current economy impacts the college students in a way that many undergraduates have to work to secure the funds for their education which, in turn, requires a more flexible class schedule. In order to accommodate the needs of university students and industry representatives, the educational units must adequately adjust their curricula in order to provide students with the opportunity to learn via traditional, blended or purely online class styles. Figure 1 depicts all three educational approaches. The first scenario represents a traditional model in which the theory and hands-on activities are delivered in-person. Note that even the traditional approach branches into two distinctive models (not shown in the figure). One branch represents the traditional engineering curriculum in which the theory of the subject is presented first, followed by the hands-on activities. There is an alternative model, the second branch of the traditional approach, commonly adopted by engineering technology programs, in which the theoretical knowledge presented in lectures is immediately reinforced with laboratory hands-on activities.

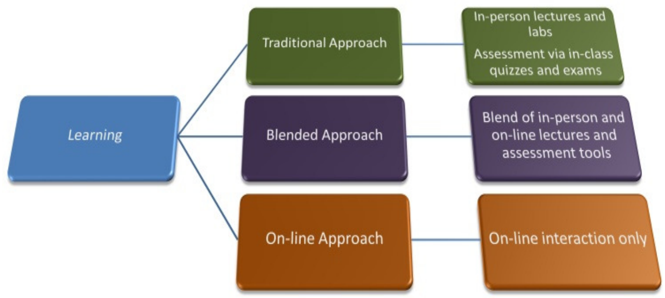

Figure 1. Educational Approaches Currently used in Academia

The second scenario represents blended learning, which combines face-to-face classroom methods with computer-mediated activities to form an integrated instructional approach.

The goal of a blended approach is to join the best aspects of both face-to-face and online instruction. Classroom time can be used to engage students in advanced learning experiences, review the material covered in the online lectures, and answer students questions, while the online portion of the course can provide students with content at any time of the day allowing for an increase in scheduling flexibility. In addition to the added flexibility and convenience to students, there is evidence that a blended instructional approach can result in learning outcome gains and increased enrollment retention [16]. Blended learning is on the rise in higher education. As of now, 93% of instructors are using blended learning strategies, and 7 in 10 expect more than 40% of their courses to be blended [17] by 2013.

The third, online approach is essentially the computer- and network-enabled transfer of skills and knowledge. In online learning, content is delivered via the Internet, audio or video tape, etc., and includes media in the form of text, image, animation, streaming video and audio. By 2006, 3.5 million students were participating in online learning at institutions of higher education in the United States [18]. According to Sloan Foundation reports [19], [20], there has been an increase of around 12–14 % per year on average in enrollments for fully online learning over the five years from 2004 to 2009 in the U.S. post-secondary system, compared with an average increase of approximately 2% per year in enrollments overall. Online engineering education provides a flexible and accessible alternative for students and people who want to pursue higher education at their own pace. Because of this, more online courses are being offered as part of traditional programs [21]. However, studies show that student participation and motivation are different from an online course [21-28]. Positive attributes of online learning include: increased productivity for independent learners; diminished fear of public speaking, which increases class participation; efficiency in assignment completion; and, easy access to all lecture materials during the entire course [21], [29]. However, critics of online learning claim that it diminishes the active process of learning and, as a result, limits development of high-level thinking skills [21], [29]. Other research has focused on the benefits of online learning for certain demographics. In particular, older students have significantly higher final course graders than their younger, 24-year-old and younger peers, and do better than counterparts who learn the same material in a class lecture style of learning [27].

Revamping the Electrical Machinery Course

The EET program in the SoT at Michigan Tech has already successfully developed and implemented several blended and online courses in the field of Robotics Automation [30], [31]. Being a core course, the EM course has been traditionally taught for years in the SoT serving electrical and mechanical engineering technology students. The EM course covers the fundamental steady-state analysis of electrical machinery, including transformers, DC machines, AC poly-phase and single phase AC machines.

Upon successful completion of this course, students should have the knowledge to:

- Analyze single- and three-phase circuits.
- Understand the principles of magnetic circuits.
- Test and model single-phase and three-phase transformers.
- Understand and predict the behavior of DC generators and motors.
- Test and model AC induction motors.
- Gain an extensive hands-on experience working with laboratory equipment.

Figure 2 depicts the course structure including the learning and assessment tools.

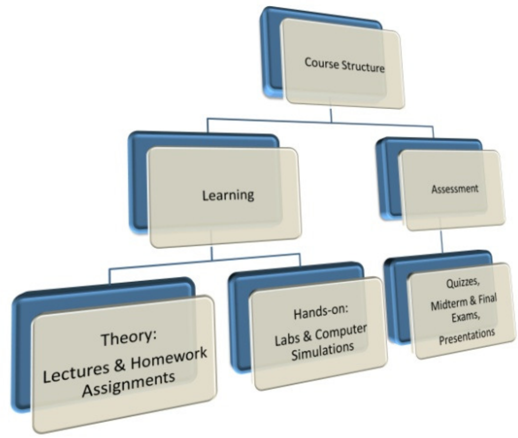

Figure 2. Electrical Machinery Course Structure

The theoretical part of the course is conveyed to students via lectures and homework assignments. It is very common that homework assignments are used as assessment tools only. In the authors' approach, the homework is assigned weekly and the solutions to the problems are provided. Homework assignments are not graded but must be worked thoroughly by the students to prepare for follow-up quizzes given one week after receiving the related assignment. This approach of assessing student knowledge has been tested for several consecutive years and has proven to be very effective in student comprehension of a subject. The other assessment tools used in the EM course are the midterm and final examinations, and student presentations.

Due to globalization, the development of student soft skills is becoming an integral part of the curriculum at most universities. In most classes offered in the SoT at Michigan Tech, students are required to research and present a technical journal paper on topics related to the class subject, followed by submission of a comprehensive written technical report. Student performance is graded based on several factors such as: the ability to extract the key technical concept of the paper, the technical knowledge of the subject matter, proficiency and confidence in presenting, and the quality of the written report. Due to the hands-on nature of the educational strategy, the laboratory component is an integral part of any course offered in the SoT, and the EM course is no exception. Every week, the students have an opportunity to apply the knowledge they gain in the classroom to industrial equipment. By the end of the course, students have at least 33 hours of hands-on activities. The knowledge gained via theoretical and practical exercises is reinforced by computer projects utilizing MATLAB simulation software.

In 2009, the first attempt at converting the existing traditional model of the EM course into the blended version was made. Utilizing the hybrid methodology, several lectures were converted to an online format and gradually introduced to a class of 40 students. Feedback collected from the students showed an interest in the hybrid/blended version of the course. A standard assessment model, previously conducted for traditionally taught EM courses, demonstrated an increase in comprehension of the subject. The students were able to re-take the lecture if needed, an opportunity that does not exist in traditional, in-class teaching. To conduct further research on the effectiveness of the hybrid model, one more hybrid version of the EM course was conducted in the fall, 2010 and 2011, semesters for classes of 48 and 46 students, respectively. The ratio of in-person to online lectures was kept at 60/40. Student feedback collected at the end of the courses again indicated a great interest in hybrid learning. Most of the students agreed that having part of the lectures in an online format not only provided them with a flexibility to adjust their busy schedule but also allowed them to better comprehend advanced material by listening to the lectures at their own pace. Students also expressed interest in the fully online and blended versions of the EM course. The students' desire to have an online version of the course was specifically expressed in the course that could be offered during summer sessions.

To further enhance and make the curriculum model more flexible, the authors developed an online version of the EM course for students currently enrolled in Michigan Tech and for industry representatives looking to improve their knowledge in the subject. The online EM course was offered in the summer of 2012 and consisted of the online learning modulus, online quizzes and exams, and intense laboratories. Only four students participated in this pilot, online course offering and completed it successfully, fulfilling all of the course requirements. The small number of students participating in the course did not allow the authors to statistically describe the success of the online model and therefore no conclusions were drawn. To collect necessary statistical data allowing the authors to evaluate the online model of the course offering and to draw rational conclusions, the next online course is scheduled for summer of 2013.

To close the loop on different educational models of the EM course, the authors also developed the fully blended version of the course. In this four-credit-hour blended version of the course, all of the lectures were delivered online and consisted of 24 online modules ranging from 35 to 55 minutes covering the same amount of theoretical material as in the traditional version of the course. Considering the blended nature of the course, the in-person class time was spent engaging students in advanced learning experiences, reviewing the material covered in the online lectures and answering students' questions. Faculty teaching the course met at least twice a week during scheduled class times on Monday, Wednesday and Friday. Monday's class for in-person interaction provided the students with the opportunity to reinforce the key concepts introduced in the online learning modules, ask questions, and engage in discussions relevant to the theoretical and practical topics revealed in the online lectures. Lecture time during Wednesday's class was devoted to student presentations. Students were required to research and present a technical journal paper on topics relevant to the class subject followed by submission of a comprehensive written technical report. Student performance was evaluated and graded by the faculty and classmates. Evaluations were based on several factors including the students' ability to extract the key technical concept of the paper, their technical knowledge of the subject matter, their proficiency and confidence in presenting, and the quality of the written report. Friday's class time was left open for the students with faculty being available for questions and discussions. The laboratory component is an integral part of any course offered in the SoT. In the EM course, students have an opportunity every week to apply the knowledge they gain in the classroom to industrial equipment. By the end of the course, students have at least 33 hours of hands-on activities. The knowledge gained via theoretical and practical exercises is reinforced by computer projects utilizing MATLAB simulation software.

Echo 360 Lecture Capturing Technology

To create the online learning modulus for hybrid, blended and online versions of the EM course, the authors utilized an Echo 360 lecture-capturing system readily available at Michigan Tech [32]. The Echo 360 system combines a view of the presenter, with a capture of the screen output, automatically making the results available shortly after a lecture is delivered. There are two options to utilize the Echo 360 capturing system at Michigan Tech: 1) to use a designated classroom equipped with a computer, cameras, microphones and digital boards; and, 2) to request the installation of a standalone Echo 360 license on the office computer. The authors utilized the second option, due to the convenience and flexibility of creating online modules from one's office. The equipment used for the in-office approach was the computer with the installed Echo 360 license, a video camera for capturing the presenter, a microphone for capturing audio and an Adesso CyberPad Digital Notebook [33]. Utilization of the CyberPad in online lecture development serves the purpose of the whiteboard in the classroom and allows the presenter to solve numerical problems in real time. Every equation or expression written on the digital pad is displayed on the computer screen and captured by the Echo 360 software in real time, which makes the online lecture very similar in appearance to the one taught in-person.

Students enrolled in the traditional or hybrid/blended versions of the course are engaged in weekly three-hour-long laboratory activities. The students enrolled in the online EM course participate in two intense laboratory sessions scheduled during two weekends. Considering the seven-week duration of the course, the two laboratory sessions were conducted after the third and sixth weeks. Prior to each laboratory session, the participating students were required to pass multiple quizzes specifically designed to test their knowledge of the subject matter being exercised in the laboratory activities. Upon completion of all of the course requirements, student knowledge was assessed using a two-hour online examination conducted via the Canvas learning environment.

Course Assessment

To effectively assess the course outcomes, direct and indirect assessment tools were implemented. In general, **direct** assessment involves looking at actual samples of student work produced in the course. These may include homework, quizzes and midterm and final examinations. **Indirect** assessment involves gathering information through means other than looking at actual samples of student work. These include surveys, exit interviews and focus groups. Each serves a particular purpose. Indirect measures can provide an evaluator with the information quickly, but may not provide real evidence of student learning. Students may think that they learned well or say that they did, but that does not mean that their perceptions are correct. It may also represent the other side of a coin—students may believe that they did not perceive some material well enough, while at the same time spending too much of their time learning the subject, but the direct assessment may indicate otherwise.

Table 1 shows the results of the survey. The authors intentionally collected the participant's age, which averaged 21. The group of students that was assessed on the perception of various learning models consisted of sophomore, junior and senior students with more weight on junior-level students. The majority of the assessed students were men with very few women, and the average age was 21 years old. An indirect assessment tool the authors developed and implemented was the completely anonymous student survey. The survey was contacted at the end of the course and was introduced to the students with the following statement:

Table 1. Student's Survey used as an Indirect Assessment Tool

5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree	Average
Average student's age	21
I am a motivated person and can take online lectures on time without being reminded.	3.33
I prefer blended learning because it provides me with additional flexibility when and where to listen to the lectures.	3.25
I prefer blended learning because I can listen to the lectures several times, if needed, resulting in better understanding of the presented material.	3.33
I prefer blended learning because I can comprehend the material on my own and still have one class a week devoted to questions	2.83
Online lectures help me to better focus on the subject without being distracted by classmates, noise, etc.	2.08
The blended learning encouraged student-faculty interaction outside of a classroom (office hours, email, etc.)	2.75
Blended learning free up class time that can be used for student presentations, which I consider to be an important tool for broadening my scope and developing my presentation skills.	2.96
Blended type of classes help me to balance between school and work	3.09
Blended type of classes help me earn higher grades	2.46
Blended type of classes help or would help me to take more classes	2.88
I would like to see more blended classes on campus	2.42
Overall the course was well designed and taught.	3.71
I gained significant practical experience in EET2233 blended course	3.33
The amount of time that I have to spend on the EET2233 blended course is more than the time I usually spend on a regular on-campus class.	3.54
I learned a great deal from this course	3.54

The purpose of this anonymous questionnaire is to collect student feedback on the effectiveness of various educational models. As you may know, the subject can be taught purely in person, purely online and by utilizing a blended learning approach, which is the mix of in person and online instructions. Please complete this survey without being biased by the fact that you may not like the online learning for whatever reason and try to base your answers only on the effectiveness of your comprehension of the material taught in EET 2233 in the Fall 2012.

Analysis of the data represented in Table 1 reveals that students' responses to some of the questions regarding the blended version of the EM course were just above average. The question *Online lectures help me to better focus on the subject without being distracted by classmates, noise, etc.* appeared to be relatively low at only 2.08. The authors attribute such a low output to the age of student participants at the age of 21 are easily distracted and are not very motivated to pursue learning on their own. Students also indicated that the amount of time they have to spend on the EET 2233 blended course is more than the time they usually spend on on-campus, traditionally taught classes. It is interesting to observe the students indication that "*they learned a great deal from the course*" at the same time stating that they "*had a hard time*" earning high grades.

To further evaluate the blended version of course success, the authors implemented the direct assessment tool. The average and standard deviation results of the final exam scores, as well as a final grade distribution were used as a rubric for this assessment. The authors also compared these data with those available from previous years when the course was taught utilizing traditional and hybrid models. Table 2 shows the average and standard deviation results, and Table 3 demonstrates the final grade distribution for the courses taught between 2009 and 2012.

Table 2. The Average and Standard Deviation Results of the EM Course Assessment for 2009-2011

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)
Average	80	78	77	81
Standard Deviation	13.4	17	17	13.8
#Students	40	48	46	45

Table 3. The Final Grade Distribution of the EM Course for 2009-2011

Year Measure	Year 2009 (Traditional Model)	Year 2010 (Hybrid Model)	Year 2011 (Hybrid Model)	Year 2012 (Blended Model)
A	13	13	13	14
AB	8	15	11	7
B	10	4	12	5
BC	3	5	5	6
C	2	1	3	6
CD	0	0	1	2
F	0	2	0	3
#Students	40	48	46	45

The direct assessment of these data reveals very interesting results. Even though student perception of the blended version of the EM course was not exceedingly positive, the direct assessment demonstrates that the performance of students participating in the blended learning course was either the same or better when compared to traditional and hybrid models. The grade distribution demonstrates that the number of A and AB students is consistent; however, there is an increase in CD and F students. This can again be attributed to the maturity stage of the students that at the age of 21 not always can be well organized without being "pushed" by the instructor to study, which results in poor performance at the end.

Conclusion

Academic programs in the School of Technology at Michigan Tech are designed to prepare technical and/or management-oriented professionals for employment in industry, education, government and business. The EET program in the SoT is constantly revamping the curriculum to meet the expectations of industry by supplying qualified technicians and technologists who have extensive hands-on experience. To further enhance and make the curriculum model more flexible, all programs in the SoT are developing and offering online courses in multiple disciplines. In this paper, the authors discussed the EM course development and implementation for students currently enrolled in Michigan Tech, and industry representatives looking to improve their knowledge of the subject.

Due to the current prevalence of blended learning in academia and on-going research on its effectiveness, any input from academic units participating in online courses, development and implementation will increase the knowledge database. Introduction of blended and online versions of the EM course will complement already existing hybrid and traditional educational models of the EM course. The availability of all of the educational models in the curriculum produces multiple benefits as indicated below:

- Time flexibility for all students.
- Flexibility in learning preferences: some students may prefer in-person learning and some may choose the purely online approach.
- Introduction of the online summer session of the course will reduce the size of the class in the fall semester. The smaller class size allows the faculty to have a more individual approach during lectures and laboratories.
- Faculty will be able to assess the effectiveness of each approach and share this knowledge with colleagues.
- Improve STEM education by adopting the most effective learning techniques.

The authors strive to improve the quality of education at the University and will continue researching the "gold standard" for pedagogical approaches. The data collected during this study will be shared with the educational community with the overall goal of improving STEM education.

References

[1] Bowden, J. A. (1989). Curriculum development for conceptual change learning: A phenomenographic pedagogy. Occasional Paper 90.3, *ERADU*, RMIT University.

[2] Diamond, R..M. (1997). Designing and Assessing Courses and Curricula: A Practical Guide. Jossey-Bass.

[3] Fink, L. D. (2003). *Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses*. Jossey-Bass.

[4] Saroyan, A., & Amundsen, C. (2004). *Rethinking teaching in higher education: From a course design workshop to a faculty development framework*. Stylus Publishing.

[5] Toohey, S. (1999). *Designing courses in Higher Education*. SRHE and Open University Press.

[6] Deek, F. P., Kimmel, H., & McHugh, J. (1998). Pedagogical changes in the delivery of the first course in computer science: Problem solving then programming. *Journal of Engineering Education*, *87*(3), 313-320.

[7] Meier, R. L., Williams, M. R., & Humphreys, M. A. (2000). Refocusing our efforts: assessing non-technical competency gaps. *Journal of Engineering Education*, *89*(3), 377-385.

[8] Massa, N. M., Masciadrelli, G. J., & Mullett, G. J. (2005). Re- Engineering Technician Education For The New Millennium. *ASEE*, AC 2005-504.

[9] Bransford, J. D., Donovan, M. S., & Pellegrino, J. W. (1999). *How People Learn*. National Academy Press.

[10] Keeton, M. T., Sheckley, B. G., & Griggs, J. K. (2002). *Effectiveness and Efficiency in Higher Education for Adults*. Kendal/Hunt Publishing.

[11] Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, 223-231.

[12] Van Eynde, D.F., & Spencer, R. W. (1988). Lecture versus experiential learning: Their differential effects on long term memory. *Journal of Organizational Behavior Teaching Society*, *12*(4), 52-58.

[13] Hake, R. (1998). Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66, 64-74.

[14] Echo 360 Survey. The Student View of Blended Learning. Retrieved March 6, 2013 from: http://echo360.com/

[15] Assessing Consumer Preferences for Continuing, Professional, and Online Higher Education (2011). Retrieved March 6, 2013 from: http://www.eduventures.com/

[16] The Sloan Consortium, Retrieved March 6, 2013 from http://www.uic.edu/depts/oee/blended/workshop/bibliography.pdf

[17] Bonk, C. J., & Graham, C. R. (2006). *Handbook of blended learning: Global perspectives, local designs*. Pfeiffer Publishing.

[18] The Sloan Consortium, Retrieved March 6, 2013, from: http://sloanconsortium.org/

[19] Allen, I. E., & Seaman, J. (2008). Staying the Course: Online Education in the United States. Needham, *Sloan Consortium*.

[20] Allen, I. E., & Seaman, J. (2003). Sizing the Opportunity: The Quality and Extent of Online Education in the United States. Wellesley, MA: *The Sloan Consortium*.

[21] Viswanathan, S. (2002). Online Instruction of Technology Courses – Do's and Don'ts. *Proceedings of the International Conference on Information and Communications Technologies in Education*, Badajoz, Spain.

[22] Whitehouse, T., Choy, B., Romagnoli, J. A., & Barton, G. W. (2001). Global chemical engineering education: paradigms for on-line technology. *Hydrocarbon Processing, 80*, 100-108.

[23] Cao, L., & Bengu, G. (2000). Web-based agents for re-engineering engineering education. *Journal of Educational Computing Research*, *23*, 421-430.
[24] Watson, J. B., & Rossett, A. (1999). Guiding the Independent Learner in Web-Based Training. *Educational Technology*, *39*(3).
[25] Deci, E. L., & Ryan, R. M. (1985). "Intrinsic Motivation and Self-Determination in Human Behavior." New York: *Plenum Press*.
[26] Uhlig, S. V. (2007). Effective Design, Instruction and Assessment of an On-Line Engineering Course. *Proceedings of the Spring Mid Atlantic Regional Conference of ASEE*, AC 2007-2815.
[27] Miller B., Cohen, N. L., & Beffa-Negrini P. (2001). Factors for Success in On-line and Face-to-face Instruction (On-line Instruction). *Academic Exchange Quarterly*.
[28] Bennett, G. (2001). Student Learning in an On-line Environment: No Significant Difference? *Quest 53* (1), 1-13.
[29] Uhlig, R., Viswanathan, S., Watson, J. B., & Evans, H. (2007). Effective Instruction of On-line Engineering Course. *Proceedings of ASEE,* AC 2007-2815.
[30] Sergeyev, A., & Alaraje, N. (2010). Partnership with industry to offer a professional certificate in robotics automation. *Proceedings of ASEE*, AC 2010-968.
[31] Sergeyev, A., & Alaraje, N. (2010). Promoting robotics education: curriculum and state-of-the-art robotics laboratory development. *The Technology Interface Journal*, *10*(3).
[32] Echo360 lecture capturing system. Retrieved March 6, 2013 from: http://echo360.com/
[33] Adesso CyberPad Digital Notebook. Retrieved March 6,2013 from: http://www.adesso.com/en/home/tablets.html

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CONDUCTING CONTINUOUS RISK MANAGEMENT USING IBM RATIONAL REQUISITEPRO SOFTWARE

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Abstract

This paper presents a continuous risk management paradigm, as well as implementing the risk information using IBM's Rational® RequisitePro® software requirement management tool. Risk management implementation is important for the following reasons: the tool assists the Project's management and team members with consistent documentation; instantiates and stores each identified risk; associates for each risk a mitigation or task plan; and, visually presents each risk with the capability to be tracked, watched or mitigated throughout the project's iterative lifecycle. The RequisitePro tool allows the capture and storage of the organizational and management system risk knowledge into a database. This risk knowledge is used for product, process and project improvement as well as the collection of metrics and lessons learned for future project references.

Introduction

Current risk management tools essentially capture and track risks early in a project's lifecycle but fall short of supporting the ongoing activities of tracking, mitigating and documenting the artifacts involved with the entire continuous risk management process. The focus of this paper is to apply a software requirements management tool, IBM Rational RequisitePro [1], to a Continuous Risk Management (CRM) paradigm developed by Van Scoy [2] and improved on by Alberts et al. [3], by adding the communicate and document element to the paradigm.

The RequisitePro tool was designed to support the entire requirements management process throughout a project's lifecycle. The artifacts and requirements information collected for a project are so similar to the risk artifacts that the tool can be applied as a risk management tool. The RequisitePro tool has the ability to: instantiate template documents; track the progress of each individual risk taken from an information sheet; track, watch and mitigate risk as a team evaluates risks activities; and, maintain schedules and traceability of risks tracked, watched or mitigated. The RequisitePro tool also maintains this information in a user-selected database. The database is used to combine and consolidate similar risks to minimize duplication, workload and time needed to resolve risks sets.

Background

Risk Management

Risk management deals with the fundamentals of knowledge engineering. Risk management provides information to the decision makers and team members before a problem occurs so that risk actions can be taken in order to avoid potential loss. Therefore, it is important that Team Risk Management [4] be an integral part of a project's management plan and not a separate activity.

The project team does a risk assessment at the beginning of a project by identifying a few risks and developing a risk management plan. This risk management plan is then placed in a binder, put on a shelf, and possibly not looked at again. However, risk management is not something a project team or manager should do only once during the project lifecycle. There is no risk management season. Also, the risks identified at the beginning of a project are not necessarily the same risks identified in the middle or near the end of the project. The CRM paradigm was derived from the Carnegie Mellon Software Engineering Institute (SEI) [5] and is defined in their CRM Guidebook [3]. Maintaining a corporate risk database allows reuse of successful risk-resolution strategies and a knowledge base of lessons learned [6]. Three additional areas where the rigorous CRM paradigm could be applied are: 1) virtual hardware risks; 2) both product- and project-related risk; and, 3) occupational safety and health. Some of the tools and techniques for each discipline may have different names, but a risk management process was employed.

The CRM paradigm can be applied to Securing Virtualized Datacenters [7] by developing a risk management plan and using a risk information sheet for each of the virtual security threats (risks) identified: Virtual Machine; Hypervisors Threats; Virtual Infrastructure Threats; and, Virtual Network Threats.

Risk and Requirements Management Tools

The CRM tools and techniques set can aid in the mitigation and control of product- and project-related risk. Product risk is defined as an unacceptable design solution–something that does not meet technical or customer requirements. Project risk is defined as the failure to conform to time and budgetary constraints [8]. The CRM tools and documentation set can also be applied to the area of occupational safety and health. One area of interest is Carpal Tunnel Syndrome (CTS), where few studies have focused on using risk assessment similar to the strain index (SI) as a mechanism to establish and monitor the effects of CTS prevention methods over time (lifecycle). One study established a methodology to reduce CTS incidents by using the SI to identify operations that have high CTS risk [9]. This study would have benefitted from the CRM iterative lifecycle process.

A survey conducted by Smith and Savage [9] shows the state of requirements for engineering tools. The survey results (of 37 vendors worldwide) show a total of 157 features of a variety of requirements for engineering tools. IBM Rational, together with their Rational Doors and RequisitePro tool are included in the 21 tools from the U.S. In order to provide model-driven traceability for software product lines, Anquetil et al. [10] identified different dimensions to track requirements, and included trace import and export, modification, query and visualization capabilities in their framework.

Goknil et al. [11] analyzed semantics of trace relations in requirements models for consistency checking and inferencing. They built a tool to support both checking consistencies of relations and inferring new ones. In addition to the two traceability relation types, RequisitePro can provide their tool accounts for more types of requirements and traceability types. In order to produce and manage quality requirements with aeronautical systems, Abo [12] developed a requirements engineering framework and implemented it using IBM Rational DOORS and IBM Rational Change tools.

Risk Management Paradigm

Van Scoy [2] developed the SEI risk management paradigm in 1992. The paradigm, illustrated in Figure 1, is a set of functions that are identified as continuous activities throughout the lifecycle of a project. The paradigm serves as a model indicating how the different elements of risk management interact and also as a framework for describing how risk management can be implemented. The paradigm has a circular form to highlight its continuous nature. The arrows signify the logical flow of information between the elements of the paradigm. Communicate & Document is the center of the paradigm. It is the means by which all information flows.

Van Scoy summarized the elements in his paradigm as:

Identify:
: Locate risks before they become problems and adversely affect the program.

Analyze:
: Turn the raw risk data into decision-making information.

Plan:
: Turn the risk information into decisions and actions (both present and future).

Track:
: Monitor the status of risks and actions taken against risks.

Control:
: Correct for deviations from the planned risk actions.

Communicate and Document:
: Provide feedback on the active risk activities, current risks and emerging risks among the paradigm elements and within the program. The documentation was added to the paradigm by Alberts et al. [3].

Figure 1. Van Scoy's Continuous Risk Management Paradigm

The Continuous Risk Management paradigm illustrates a set of functions that are identified as continuous and iterative activities throughout the lifecycle of a project. The paradigm is a conceptual, or abstract, view of risk management.

Risk identification is the first element in the risk management paradigm. The goal of risk identification is to identify the risks to be managed before they can adversely affect a program and to incorporate this information into the project management process. The risk team uses techniques to discover risks by exploiting the collective knowledge of the program team. Since each member of the program team has particular knowledge about the project, anyone involved can be useful in identifying risks.

Risk analysis is the second element in the risk management paradigm. The purpose of risk analysis is to convert risk data into useable risk management information for determining priorities and making decisions. Each risk must be understood sufficiently to allow a manager to make decisions. Risk analysis sifts the known risks and places the information in the hands of the decision maker. Analysis provides the information that allows managers to work on the right risks.

Risk planning is the third element in the risk management paradigm. This element includes developing actions to address individual risks, prioritizing risk actions and orchestrating a risk action plan for each risk. An individual risk action plan could take many forms, for example:

- Mitigate the impact of the risk by developing a contingency plan (with a triggering event) should the risk occur.
- Avoid a risk by changing the product design.
- Accept the risk and take no further action, thus accepting the consequence if the risk occurs.
- Study the risk further to acquire more information and better determine the uncertainty or loss associated with the risk.

The key to risk planning is to translate risk information into planning decisions and mitigating actions (both present and future) and implementing those actions.

Risk tracking is the fourth element in the risk management paradigm**.** The purpose of risk tracking is to collect accurate, timely and relevant risk information and to present it in a clear and easily understood manner appropriate to the personnel or group receiving the status report. Risk tracking is required in order to ensure effective action plan implementation. This means that the risk team must devise the risk metrics and triggering events needed to ensure that the planned risk actions are working. Tracking is the watchdog function of the risk action plan. Tracking is done by the person(s) responsible for monitoring "watched" or "mitigated" risks. Project personnel use the status report information, generated during tracking, in the control function of the paradigm to make decisions about managing risks.

Risk control is the fifth element in the paradigm. Once the risk metrics and the triggering events have been chosen, there is nothing unique about risk management. Rather, risk management melds into program management and relies on program management processes to control the risk action plans, correct for variations from the plans, respond to triggering events and improve the risk management process. In fact, if risk management is not integrated with day-to-day program management, it will soon be relegated to an ineffective background activity.

Risk "communicate and document" is at the center of the risk management paradigm because, without effective communication, no risk management approach is viable. Communication is critical because it facilitates interaction among the elements of the paradigm. There are higher-level communications to consider as well. Risks must be communicated to the appropriate organizational levels so the risks can be analyzed and managed effectively. This includes levels within the development organization, within the customer organization and, most especially, across that threshold between the developer and the customer. Communication is present in all paradigm functions and is essential for managing risks. Communication of risk information is often difficult because the concept of risk deals with probability and negative consequences.

Project Risk Management is defined as the systematic process of identifying, analyzing and responding to risk, according to the Project Management Institute (PMI). Project risk management is intended to support project managers in managing risk and minimizing the impact of risk on the project outcomes and outputs. Kimbrough and Componation [13] analyzed the importance of organizational culture in implementing risk management in organizations, and found that organic cultures make greater progress in implementing a risk management program. Yeo and Ren [14] identified a need for progressive risk management capabilities in inherently complex projects (in terms of tasks and human issues). The framework they proposed is a good application of the risk management paradigm discussed above, since it includes a change management framework that deals with risk planning and control processes, as well as organizational and people contexts of the complex project.

In a recent study conducted by Krane et al. [15] on the relationship between the project manager and the project owner, and the impact of this on project risk management, has shown that the main focus is on operational risks (identified as relating to the project's direct results). In some cases, however, due to cost justifications, a formal risk management process is not always applied [16]. In a further study conducted by Kutsch and Hall [17], the issue of Information Technology project managers deliberately ignoring certain risks and finding them irrelevant has been addressed and, similar to their previous study, concluded that project risk management, when not applied correctly, may be counterproductive in some cases.

RequisitePro

Rational RequisitePro is a requirements repository tool that organizes requirements and provides traceability and change management throughout the project lifecycle. RequisitePro requirement management software was selected to show how it handles risk (requirement) traceability. Two views will be given: 1) Risk Traceability Matrix View to show risk mitigation traced from the risk matrix, and 2) Risk Traceability Tree View to show risk action traced into a risk. The views show the preventative, contingency and second-level actions traced to the risks. If the risk or the action changes, RequisitePro gives a visible indication (suspect links) of potential impacts to the Project Risk Management Plan and other project activities.

Rational [1] defines a requirement as "a condition or capability to which the system must conform." The risk statement is similar to the requirement statement. The intent of the risk statement is that it be clear, concise and sufficiently informative such that the risk is easily understood. The risk statements in standard format shall contain two parts: the condition and the consequence. The condition-consequence format provides a complete picture of the risk, which is critical during mitigation planning. The risk statement is read as follows:

Given the ***<condition>****; there is a possibility that* ***<consequence>*** *will occur.*

A RequisitePro project is defined as a requirements database and its related documents. A project manager determines the project structure, sets up security permissions for the project's users, and creates a RequisitePro project. Each RequisitePro project has its own database, where all of the requirements for a project are stored. In the project database, requirements can be added, modified or deleted. When requirements are changed, the changes are updated in the database. These project activities and database can easily be applied to the CRM paradigm.

The currently supported databases are: Microsoft Access, Oracle and Microsoft SQL Server. The back-end database used depends on the size of the project team, location, logged-on users and cost constraints. For small work groups, Microsoft Access is recommended and was used for this study. RequisitePro has version control to let the project manager trace change by archiving projects. Version control helps the project manager keep a record of changes to project files during the lifecycle. Risk attributes must be ranked, tracked, mitigated or deleted when they are no longer a risk and have become a problem.

The Word Workplace is the file within RequisitePro where requirements are created and modified in a document. These can be RequisitePro documents or Word documents. The Views Workplace is a window to the database. Requirements, their attributes and their relationships to each other are displayed and managed in views. The requirement Workplace thus becomes the risk workplace. RequisitePro includes a Web interface, making requirements accessible to all team members, especially in remote locations or in a multi-platform environment. Van Epps [19] first presented an Automating Risk Management process with RequisitePro.

Views present information about the project, a document or requirements graphically in a matrix or in an outline tree. Views display the attributes assigned to requirements, such as status and priority, or the relationships between different types of requirements (similar to a set of risks). The views can be grouped in packages and traced to one another. RequisitePro has three kinds of views:

1. The Attribute Matrix View displays all requirements (risk) of a specified type. The requirements are listed in the rows and their attributes appear in the columns.
2. The Traceability Matrix View displays the relationships (traceability) between types of requirements (risk).
3. The Traceability Tree displays the chain of traceability to or from requirements (risk) of a specified type.

A requirements document is a specification that captures requirements, describes the objectives and goals of the project and communicates development effort. The Risk Management Plan, Risk Implementation Plan and Detailed Risk List are similar documents that have existing formatted templates in Rational Suite Enterprise. Any Word document can be associated with a project and made available in the document list when a project is opened. This includes the risk mitigation and task plan documents. Requirement type is a template for inserting the project's requirements. This pull-down-window view is employed as a template for inserting the projects risks. Requirement types are used to classify similar requirements so they can be managed, defined in a common set of attributes, display style, tag numbering and more. With this overview of the Rational RequisitePro capabilities, it is easy to identify similarities and substitute the risk statements for the requirement statements and input the contents contained in each risk information statement to the RequisitePro Views.

The risk information sheet records the information gathered during each of the paradigm's functions. Figure 2 is an example format used for a risk information sheet. The contents in the fields of the risk information sheet are the values input into the views and packages managed by RequisitePro. A mitigation or task plan format was also developed for each risk that is mitigated and tracked. The mitigation or task plan is also stored in the database and tracked by the associated risk ID.

<table>
<tr><td>ID</td><td colspan="2">Risk Information Sheet</td><td>Identified:</td></tr>
<tr><td>Priority
Probability
Impact</td><td colspan="3">Statement</td></tr>
<tr><td>Timeframe</td><td>Originator</td><td>Class</td><td>Assigned To:</td></tr>
<tr><td colspan="4">Context</td></tr>
<tr><td colspan="4">Approach: Research / Accept / Watch / Mitigate</td></tr>
<tr><td colspan="4">Contingency Plan and Trigger</td></tr>
<tr><td colspan="3">Status</td><td>Status Date</td></tr>
<tr><td>Approval
____
________</td><td>Closing Date
__/__/__</td><td colspan="2">Closing Rationale</td></tr>
</table>

Figure 2. Example Risk Information Sheet and Fields.

During IDENTIFY, the following fields are completed by the project team members:

- *ID*: Unique identifier for the risk, numeric or alphanumeric, assigned by project or organization or CM office
- *Identified*: Date when the risk was identified
- *Statement*: Statement of the risk
- *Origin*: Organization or person who identified the risk
- *Context*: Associated information that clarifies the risk

During ANALYZE, the following fields would be completed:

- *Priority:* The priority ranking of the risk
- *Probability:* The likelihood of occurrence—exact value depends on the level of analysis
- *Impact:* The degree of impact—exact value depends on the level of analysis
- *Timeframe:* The timeframe in which action is needed
- *Class:* The classification of the risk (could be more than one value) and the class or group the risk belongs to

During PLAN, the following fields would be completed:

- *Assigned to:* Who is responsible for mitigating the risk
- *Mitigation strategy:* The selected mitigation strategy for mitigating the risk
    - This field can also be used to document the other approaches that can be taken and their information (e.g., research approach with its research plan; watch approach with its tracking requirements; accept approach with its acceptance rationale)

During TRACK, the following fields would be completed:

- *Status/status date:* Running status information that provides a history of what is being done for the risk and of any changes in the risk
- *Probability:* Likelihood of occurrence—exact value depends on type of analysis
- *Impact:* Degree of impact—exact value depends on type of analysis
- *Timeframe:* Timeframe in which the risk will occur or action is needed
- *Priority:* Priority ranking of the risk

During CONTROL, the following fields would be completed:

- *Approval*: Approval for mitigation strategies or closure (for transferred risks, this may require the transferor's signature)
- *Closing date:* The date when the risk was closed
- *Closing rationale:* The rationale for closure of the risk (e.g., probability is zero)

During continuous COMMUNICATE and DOCUMENTION, the following documents would be selected, initialized, maintained and tracked:

- Risk Management Plan
- Risk Implementation Plan
- Risk List Document
- Risk Analysis Reports
- Risk Mitigation Status Reports
- Risk Database
- Risk Tracking Logs
- Test Reports

CRM Applied to RequisitePro

A hypothetical project-manager scenario is depicted to identify the possible risk associated with him and the project. One potential risk is identified as an example. The risk is stated and implemented into a RequisitePro project named CRM_Risk. Six views show a sample of the RequisitePro tool capabilities applied to the risk management project. The six views are:

1. Microsoft Access Risk Management Document Database
2. Risk Properties Dialogue Box
3. Risk List Attribute Matrix
4. Risk Mitigation Attribute Matrix
5. Mitigation Traced From Risk Matrix
6. Risk Actions Traced Into Risks

The following example information concerns the project manager and the software engineers working on the software system the team will build. This is the first system the project manager has managed of this magnitude and complexity. The project manager believes it is going to be a very positive experience for him and the rest of the software engineers on the project. All of his other projects were hardware control systems prior to this. The software engineers working for the manager are entry-level people just out of college. The project manager thinks that software can fix just about any problem the hardware group comes up with. The waterfall lifecycle model [19] is what the project manager will use on this project, and he foresees no problems with using this model.

The project is in the requirements stage of the lifecycle; the project manager thinks one of the most exciting opportunities of a new project is that this is the first project at the company to use object-oriented design (OOD) and the C++ programming language. Every one of the software engineers has the chance to learn something new on this project. This will put the software engineers on the forefront of the technology curve and really bring the software team into the future. The manager has also selected one of the newest C++ compilers with all of the latest features to help improve the efficiency of software developments.

Given this scenario, the CRM_Risk Project was created using a RequisitePro interface to establish a Microsoft Access database in order to store the new document sets that were created before the IDENTIFY stage began. Figure 3 is a Microsoft Access window displaying four template documents instantiated for and used throughout the lifecycle of the project. This figure shows that the RequisitePro tool will support and interface to one of three databases: Microsoft Access, Oracle and Microsoft SQL Server. The back-end database to be used depends on the size of the project team, location, logged-on users and cost constraints. For small work groups, Microsoft Access is recommended and was used in this study.

The documents are:

1. Risk Management Plan
2. Risk Implementation Plan
3. Risk List Document
4. Risk List Glossary

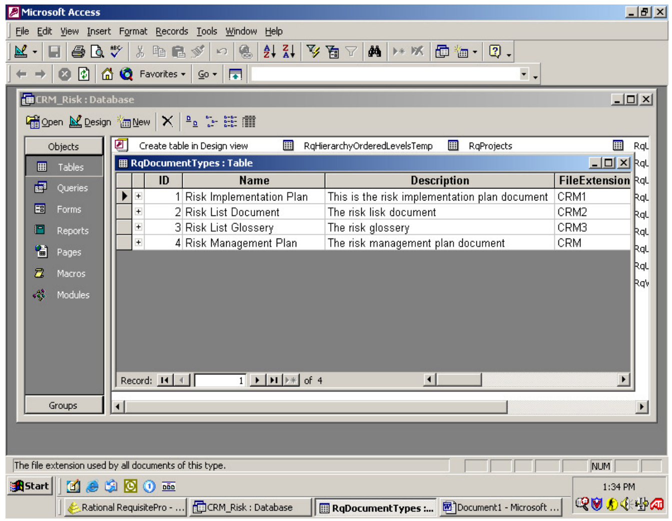

Figure 3. Microsoft Access Risk Management Document Database

There are numerous risk statements that can be obtained from this scenario. The RISK1 condition-consequence statement is the risk selected and shown in the six RequisitePro views.

This is the first time that the software engineers will use OOD; the engineers may have a lower-than-expected productivity rate and schedules may slip because of the associated learning curve

The following risk context statement taken from the Risk Information Sheet is associated with the RISK1 OOD risk statement.

Object oriented development is a very different approach that requires special training. There will be a learning curve until the entry-level software engineers are up to speed. The time and resources must be built in for this or the schedule and budget will be overrun

By creating a Package, Risk-Types, each risk is entered using the Requirements pull down menu view. The Dialogue box (see Figure 4) is used to create or revise a risk gathered from the risk information sheet. The risks are entered under General using Type, Name and Text, where:

- Type: The new risk inherits the risk type (RISK) displayed in the Attribute Matrix
- Name: Displays the name associated with the risk
- Text: Displays the risk condition and consequence statement

The engineer has five additional fields that are input-based on the iterative stage of the CRM process. The five fields are:

1. Revision
2. Attributes
3. Traceability
4. Hierarchy
5. Discussion

For example, the Traceability view is input during the Track stage. The Hierarchy can be used to establish the importance of this risk within the risk collection. The Discussion displays the detailed context statement.

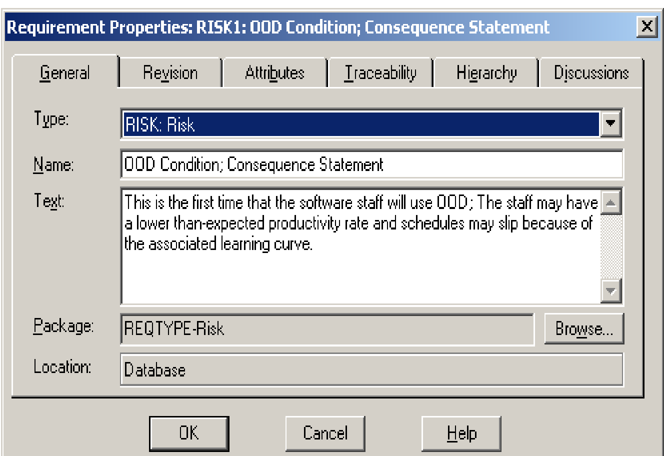

Figure 4. Risk Properties Dialogue Box

As the risk engineering team progress through the IDENTIFY and ANALYZE stages, they develop the Risk List Document using information taken from the fields of the Risk Information Sheet. The Risk List Document contains the detailed information about each risk and servers as a deliverable. As the risks are entered into the Package, Risk-Types, the risk list is displayed in a matrix view. Figure 5, Risk List Attribute Matrix, provides the team members, working on the CRM_Risk project, the risk list view. Risks are arranged in rows and listed by a risk number. Attributes are arranged in the following columns:

1. Difficulty of Detection
2. Likelihood
3. Potential Impact
4. Overall Risk
5. Notes

These are the attributes assigned in the PLAN, TRACK and CONTROL stages of the CRM paradigm. A text pane, located at the bottom, displays the description of a risk in its entirety; the risk statement is also shown in the lower-left view element.

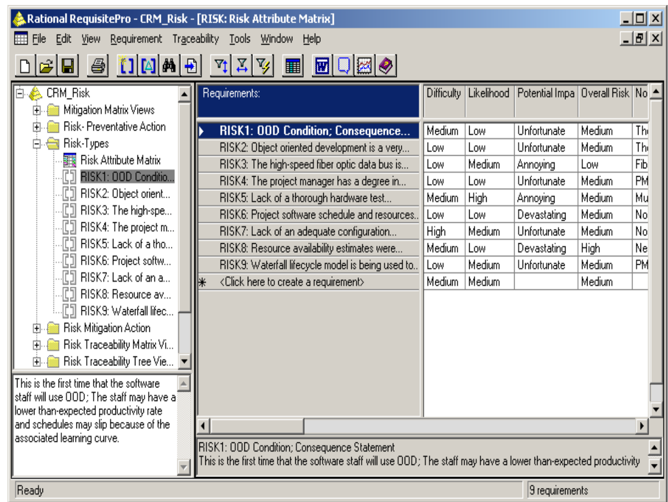

Figure 5. Risk List Attribute Matrix

During the PLAN stage, the team, using the Package, Risk Mitigation Action, builds a Mitigation Attribute Matrix for each risk decided to mitigate. Two similar Packages (Risk Watch Action and Risk Accept Action) would be instantiated for risks to watch and accept. Figure 6 shows the tree and matrix views. There are five fields to input attributes:

1. Approval
2. Owner
3. Trigger
4. Cost
5. Notes

The MITIGATE pending box is used to input the next mitigation risk (MITIGATE6 Project Manager). In the example, the text field proposes to assign a new project manager. The information for the selected item is displayed in the bottom, lower-right section of the view.

During the lifecycle of the CRM_Risk project, the TRACK and CONTROL stages use views selected from the Package, Risk Traceability Matrix Views. The Traceability Tree, shown in Figure 7, provides a graphical view of relationships to or from risk or sets of risks, including direct, indirect and suspect traceability relationships. The risk statements are in the matrix rows and mitigation actions in the columns. Another view, PREVENT, was developed to plan risk prevention actions and trace to the mitigation actions.

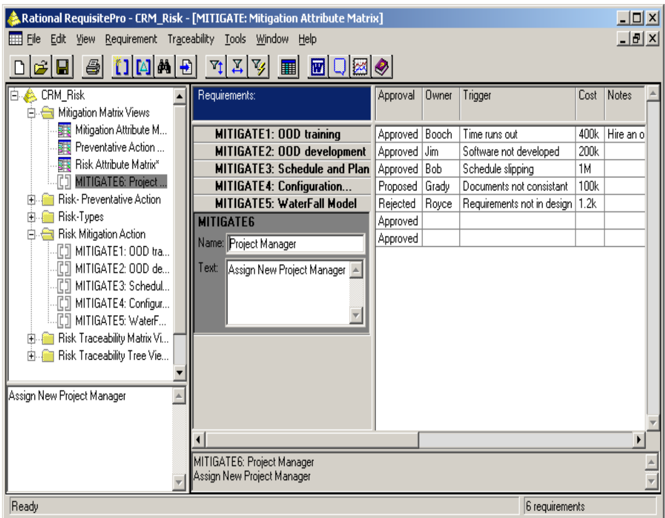

Figure 6. Risk Mitigation Attribute Matrix

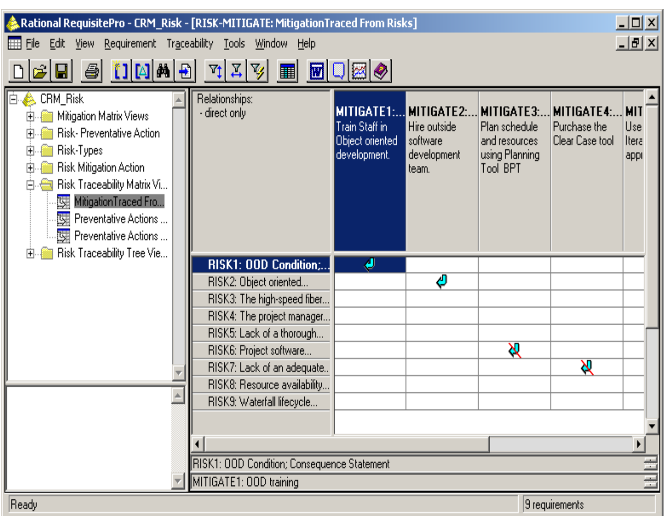

Figure 7. Mitigation Traced from Risk Matrix

In the Package, Risk Traceability Tree View, shown in Figure 8, are risk mitigate and prevent actions traced to the risks. This view shows each risk, the mitigation plan and the prevention tactics. For each risk, a sliding window gives the mitigation prevention number traced to the risk.

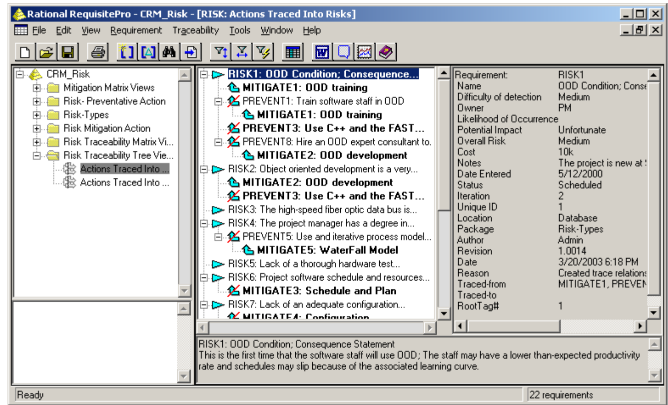

Figure 8. Risk Actions Traced Into Risks

Conclusion

The overall process flow for the continuous risk management paradigm was presented. Each stage of the paradigm was dissected and the activities inserted into RequisitePro. RequisitePro is a powerful requirement tool, which was easily applied to risk management. The tool helps teams manage project risks comprehensively, promotes communication and collaboration among team members, and reduces project uncertainty. RequisitePro offers the power of documentation and a database linked to all items of a Project. A very important feature of RequisitePro is that, if any item in a View is changed, the associated items are simultaneously changed in all of the other Project Package Views.

Its robust architecture maintains live risk documents that are dynamically linked to a database for trace, sort and query capabilities. This allows system engineers to easily organize and prioritize their risk in order to trace, mitigate and prioritize relationships between risk and track changes that affect schedules. The traceability features visually indicate how changes affect the project, giving engineers the ability to perform real-time impact analyses and allowing them to make informed decisions for management or resource allocation. As a result, the project manager is better able to manage risk, and their project's integrity is maintained. RequisitePro captures the change history for each risk, which provides an audit of the project's risk evolution.

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The authors would like to acknowledge the IBM SEED Program. The SEED has helped our institute to teach advanced Software Engineering practices based on IBM's industrial products, tools and techniques. The Rational products address the entire software-development lifecycle and are used in our engineering programs.

Teaching students continuous risk management implementation is important in order to show them how the tool will: assist the project management and team members to establish and use consistent documentation; instantiate and store each identified risk; associate for each risk a mitigation or task plan; and, visually present each risk with the capability to be tracked, watched or mitigated throughout the project's iterative lifecycle. The IBM Rational RequisitePro tool was used to show the students how to capture and store the organizational and management system risk knowledge into a database. The students gain hands-on risk management knowledge that can be used for product, process and project improvement. They learn how to write risk statements, collect risk metrics and capture the risk lessons learned for future projects

References

[1] IBM Rational® RequisitePro®. Retrieved February 10, 2013, from IBM Software website: http://www-01.ibm.com/software/awdtools/reqpro/

[2] Van Scoy, R., (1992). *Software Development Risk: Opportunity, Not Problem* (CMU/SEI-92-TR-030). Retrieved February 10, 2013, from the Software Engineering Institute, Carnegie Mellon University website: http://www.sei.cmu.edu/library/abstracts/reports/92tr030.cfm

[3] Alberts, C. J., Dorofee, A. J., Higuera, R. P., Murphy, R. L., Walker, J. A., & Williams, R. C. (1996) *Continuous Risk Management Guidebook.* Carnegie Mellon University.

[4] Higuera, R., Gluch, D., Dorofee, A., Murphy, R., Walker, J., & Williams, R. (1994). *Introduction to Team Risk Management (Version 1.0), an* (CMU/SEI-94-SR-001). Retrieved February 10, 2013, from the Software Engineering Institute, Carnegie Mellon University website: http://www.sei.cmu.edu/library/abstracts/reports/94sr001.cfm

[5] Higuera, R., Dorofee, A., Walker, J., & Williams, R. (1994). *Team Risk Management: A New Model for Customer-Supplier Relationships* (CMU/SEI-94-SR-005). Retrieved February 10, 2013, from the Software Engineering Institute, Carnegie Mellon University website: http://www.sei.cmu.edu/library/abstracts/reports/94sr005.cfm

[6] Hall, E. M. (1998). *Managing risk: Methods for Software Systems Development*. (1st ed.). Addison-Wesley.

[7] Mirzoev, T., & Yang, B. (Spring 2010). Securing Virtualized Datacenters. *International Journal of Engineering Research and Innovation*, *2*(1), 23-29.

[8] Johnson, M., D., & Parthasarathy, A. (Spring 2010). Evaluating the Accuracy, Time, and Cost Trade-Offs Among Alternative Structural Fitness Assessment Methods. *International Journal of Engineering Research & Innovation*, *2*(1), 62-68.

[9] Smith, G., C., & Savage, M., D. (Spring 2009). Identifying Prevention Methods to Reduce CTS Incidents: Gased on Analysis of Employee Perception and By Utilizing the Strain Index. *International Journal of Engineering Research and Innovation*, *1*(1), 17-20.

[10] Anquetil, N., Kulesza, U., Mitschke, R., Moreira, A., Royer, J., Rummler, A., et al. (2010). A model-driven traceability framework for software product lines. *Software Systems Model*, *9*, 427-451.

[11] Goknil, A., Kurtev, I., Van den Berg, K., & Veldhuis, J. (2011). Semantics of trace relations in requirements models for consistency checking and inferencing. *Software Systems Model, 10*, 31-54.

[12] Abo, R. (2010). Introduction to a Requirements Engineering Framework for Aeronautics. *Journal of Software Engineering and Applications*, *3*, 894-900.

[13] Kimbrough, R. L., & Componation, P. J. (2009). The Relationship between Organizational Culture and Enterprise Risk Management. *Engineering Management Journal, 21*(2), 18-26.

[14] Yeo, K. T., & Ren, Y. (2009). Risk Management Capability Maturity Model for Complex Product Systems (CoPS) Projects. *Systems Engineering, 12*(4), 275-294.

[15] Krane, H. P., Olsson, N. O. E., & Rolstadas, A. (2012). How Project Manager-Project Owner Interaction Can Work Within and Influence Project Risk Management. *Project Management Journal, 43*(2), 54-67.

[16] Kutsch, E., & Hall, M. (2009) The Rational Choice of Not Applying Project Risk Management in Information Technology Projects. *Project Management Journal, 40*(3), 72-81.

[17] Kutsch, E., & Hall, M. (2010) Deliberate ignorance in project risk management. *International Journal of Project Management*, *28*, 245-255.

[18] Van Epps, C. (2000). *Automating Risk Management with Rational RequisitePro*. Paper presented at the Rational Users Conference in Session RM01, Orlando, FL.

[19] Royce, W. W. (1987). Managing the development of large software systems: concepts and techniques. *International Conference on Software Engineering - ICS*, (pp. 328-338).

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AN ENGINEERING RESEARCH PROGRAM FOR HIGH SCHOOL SCIENCE TEACHERS: FEEDBACK AND LESSONS LEARNED FROM THE PILOT IMPLEMENTATION

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Abstract

The engineering research program for high school science teachers at Central Michigan University was created through the National Science Foundation's Research Experience for Teachers program with the goals of providing high school teachers with a broad overview of engineering, enhancing their engineering skills through research experience, and assisting them in taking their new skills back to their respective high schools for curriculum development. Seven in-service teachers and five pre-service teachers participated in a six-week research program during which they completed a research project with an underlying theme of *smart vehicles*. Through numerous feedback surveys, reflection sessions and lessons learned during the program, it was found that all participants were able to engage in a meaningful research experience that allowed them to understand and practice the engineering research process and enhance their teaching effectiveness. The overall combination of research and professional coaching sessions created an effective professional development program for high school teachers, thus contributing to the enhancement of K-12 education. In addition to presenting details on the program, this paper includes lessons learned by the engineering faculty with the hope that this information will help others who are planning to initiate a similar program at their respective institutions.

Introduction

In recent years, Science Technology Engineering and Mathematics (STEM) educators, professionals, business leaders and policymakers have recognized and highlighted the requirement to build a strong and technologically trained workforce. This requires a strong K-16 education system with qualified and trained educators. While American college-level educators are willing to train this workforce, the K-12 education system is currently suffering from a crisis of inadequate teacher preparation in STEM disciplines leading to low student preparation and performance [1]. On the top of this, limited opportunities are available for K-12 teachers, and soon K-12 science teachers will be required to follow the Next Generation Science Standards (NGSS) with a strong overarching focus on engineering [2].

As most K-12 science teachers do not have any training in engineering concepts, there is a lack of high-quality curricular materials and professional development programs in this area [3]. So, new, inclusive professional development programs for K-12 teachers are required to address the new education standards for improved classroom teaching and learning [4-7]. These professional development programs are a catalyst for K-12 educational reform, and should include technological content and resources that expand educators' knowledge and ability to apply it in their classroom. Some of the key factors for these professional development programs include: 1) active engagement with hands-on activities related to the new science standards; 2) collaboration, sharing and exchange of ideas and practices; 3) interaction with college-level educators; and, 4) active participation in pedagogical workshops.

Based on these key factors and information available in the Council of Chief State School Officers report [8], the National Science Foundation (NSF) Research Experience for Teachers (RET) program at Central Michigan University (CMU) was designed with the following features: 1) Active Learning: High school science teachers were actively involved in an engineering research project with a focus on smart vehicles; 2) Coherence: Activities were built on what they learned and led to more advanced work; 3) Content Focus: Content was designed to help prepare teachers for the new science standards [2] by enhancing their knowledge and skills; 4) Duration: Professional development for teachers extended over six weeks during the summer with a follow-up for lesson-plan development during the school year; 5) Collaboration: In-service teachers (ISTs) worked with pre-service teachers (PST), undergraduate engineering students (ES) and engineering faculty to learn from each other; and, 6) Collective Participation: All participants worked together in teams, met with the entire participant group to discuss strategies and presented their findings at a premier technical conference or published them in a journal.

Previous Work

Identifying the needs and challenges of preparing K-12 teachers, several universities have initiated professional development programs. With the primary theme of biomedical engineering, Vanderbilt University implemented the RET program [9], [10], where participants follow a legacy model of designing instructional resources while in the program and taught them in the following year in their respective classrooms. Similarly, the Georgia Institute of Technology's Physics RET program showed that teachers improved their ability to encourage students to pursue a science or engineering degree [11]. Also, the Texas A&M RET program focused on improving teacher knowledge of careers in engineering [12]. In addition, Tennessee Tech University (TTU) proposed a research program involving ISTs, PSTs, ESs, and a faculty member to work on a research project for five weeks [13]. One other similar RET site present in the literature was from the University of Pittsburgh [14], where ISTs are required to work for eight weeks during the summer on a research project, implement 6-8 week design-based learning modules in their classes, conduct design competitions for students in classes of the RET teachers, and offer summer internships at the university for the winning high school students.

All of these state programs and others [15-19] differ in their unique goals and activities, yet they share the same goal of professional development of K-12 teachers to better prepare the future workforce. Successful implementations of these professional development programs require significant contributions from engineering faculty and the university administrations. The ISTs, PSTs and ESs typically have financial incentives for participation in these programs, such is usually not the case for engineering faculty. These faculty members participate in part because preparing K-12 teachers helps better prepare incoming freshman, and increase student recruitment through publicity at schools of participating teachers.

By evaluating these objectives requires a longitudinal study of the program over an extended period of time, it is the authors' belief that sharing the initial reflections of all of the participants (engineering faculty, ISTs and PSTs) will be beneficial for the engineering education community. Although substantial studies exist to highlight the significance of other RET programs, very few, if any, present the participants' reflections and a qualitative assessment of the respective programs. In light of this limitation, this paper presents an overview of the CMU–NSF RET program, initial reflections of all participants, a qualitative assessment of the initial implementation, lessons learned, and improvements planned for next year.

RET Program Goals and Hypotheses

The National Science Foundation supports the professional development of K-12 teachers through several programs including, but not limited to, the RET [20]. The NSF's stated primary objective for the RET program is to support the active involvement of K-12 science, technology, engineering, computer and information science, and mathematics (STEM) teachers and community college faculty in engineering and computer science research in order to bring knowledge of engineering, computer science, and technological innovation into their classrooms. Identifying the limited professional development opportunity available for K-12 teachers in the Michigan rural areas, in the fall of 2011, CMU proposed an RET site to engage K-12 teachers of rural Michigan in a six-week research program with the underlying theme of smart vehicles, and was awarded support for three years.

In the summer of 2012, CMU initiated the RET program with the following key aspects: active learning, coherence, content focus, duration, collaboration and collective participation. The primary goals of the CMU–NSF RET program are: 1) establish a collaborative partnership between the various entities of the university, high school STEM ISTs and PSTs, and assessment leaders at an external organization; 2) provide a STEM-based platform through which the ISTs and PSTs can gain exposure to several engineering concepts with a focus on smart vehicles; and, 3) facilitate the development of high school STEM-based classroom instructional materials with ISTs and PSTs who serve rural Michigan areas.

In order to evaluate the program goals, the following questions were asked:

a) Could ISTs and PSTs engage in an engineering research project that would allow them to both implement and understand the research process?
b) Could teachers develop and implement K-12-level instructional materials based on research experience?
c) Could this program positively affect teachers' opinions and attitudes towards engineering and the use of challenge-based instructional materials?
d) How do teachers develop as scientific researchers when immersed in a research project?
e) How well do ISTs and PSTs understand the research process after participation in this program?

Several hypotheses were established prior to beginning of this program. ISTs would have the skills necessary to engage in an engineering research project. ISTs and PSTs would understand the methodology of conducting research to help translate their research experience into classroom instructional resources. All participants would gain an understanding of the research process after participating in this program, and also assist the engineering faculty in advancing their respective research projects.

Program Description

Participant recruitment and program efforts started right after receipt of the RET site award notification in April, 2012. Initially, the principal investigator (PI) worked with the faculty members to develop diverse projects with the underlying theme of smart vehicles. During the same period, the PI and CO-PI drafted the application material for participant recruitment and informed schools in the Intermediate School Districts (ISD) of the opportunity available. From the pool of applications received, 12 (7 ISTs and 5 PSTs) were chosen for the pilot program in summer of 2012. Based on the number of participants recruited, six teams would be formed with each team containing one IST, one PST, one undergraduate ES and one engineering faculty member. This model would bring forward the strengths (teaching experience of basic sciences from ISTs, enthusiasm and willingness to try new strategies from the PSTs, hands-on experience and motivation to engage in research from an undergraduate ES and mentoring skills and technical expertise of an engineering faculty member) of each participant in order to reinforce the learning and teaching environment within each team.

The CMU–NSF RET program was a six-week program that began with a one-week orientation session for all IST and PST participants. This orientation week started with welcome and participant introductions, followed by an explanation of the rationale behind the chosen team model, and engineering faculty members presenting their respective projects. Upon completion of these project presentations, all ISTs and PSTs were requested to write short descriptions of a few projects and how they could adapt each project to their classrooms in order to improve the basic science classes. Accordingly, teams were formed by the end of week one based on this statement and optional professor ratings of the participants' interest in the project. In addition, other sessions attended by the participants include obtaining identification cards, parking permits, CMU campus tours, engineering and technology building tours, coaching sessions on team building, classroom flipping techniques and engineering programs at CMU [21].

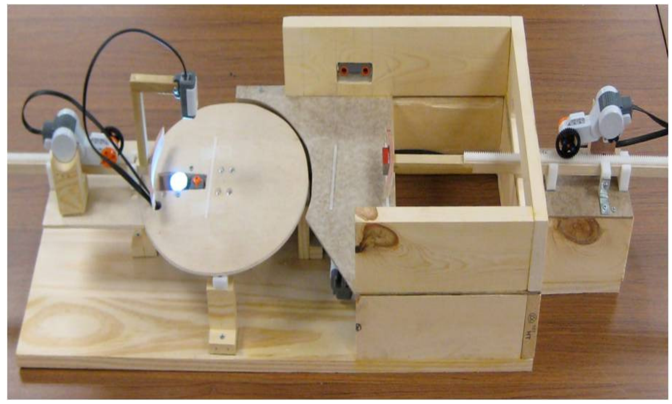
At the beginning of week two, participants spent 20 hours on research, eight hours on coaching (teacher training), four hours on group reflections and team planning, and three hours visiting other research labs and attending talks by various individuals. Some of the research projects that participants were involved in include: i) semi-autonomous tour guide robot [22-24]; ii) automated waste sorter; iii) sensor development for unmanned vehicles [25-26]; and, iv) robot tele-operation, as shown in Figure 1. During the research portion of the program, each participant worked closely with the respective engineering faculty to clearly articulate the goals and expectations, monitor daily and weekly progress and seek assistance as necessary. To accomplish the tasks set forth, ISTs and PSTs were provided extensive assistance not just by the engineering faculty but also by the ESs. Once the initial research training of the participants was completed (mostly in week two), teams focused on their own research projects through project-based modules [27] and problem-based learning [28] for higher knowledge retention. Although each project had its own challenges, participants dealt with several engineering-related research problems that can be classified as: 1) process optimization; 2) circuit design and testing; 3) manufacturing tolerances; 4) literature reading and surveying; and, 5) advanced engineering software usage for material characterization.

During the coaching sessions, participants were introduced to various effective classroom teaching activities, critical thinking skills, review of next-generation science standards (NGSS) and hands-on learning activities. During the group reflections and team planning time, all participants gathered and discussed what they had accomplished that respective day/week, and how they could infuse these accomplishments into their classroom teaching. These group reflections provided many advantages such as an opportunity to learn about other projects, share strategies for solving similar problems, and increase rapport among all participants. In addition to participating in research, coaching sessions and group reflections, participants were also introduced to different research activities through other engineering and science faculty presentations and visits to their respective research labs.

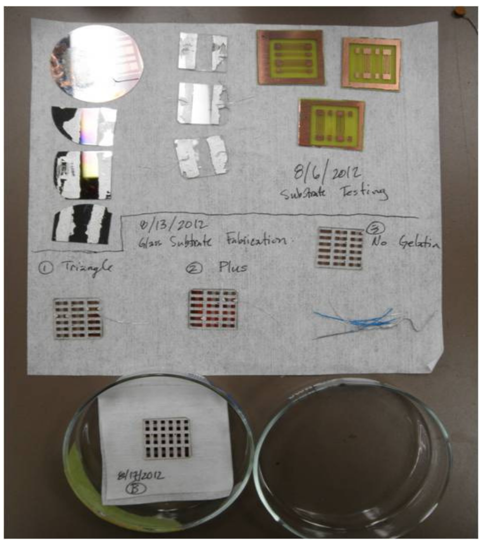
The CMU–NSF RET program concluded with a poster presentation session detailing the research accomplished. During the post academic year, trained academic and leadership coaches from the Science, Mathematics, Technology Center (SMTC) carried out the professional development activities through class visits, coaching and curricular activity development. With one of the challenges faced by ISTs being translating their summer research into high school science classes per the new common-core standards adopted by Michigan, these coaches worked with ISTs and provided guidance to design the necessary lesson plans. Several engineering-related classroom activities were planned and executed with these coaches through the high school visits. ISTs and PSTs worked together on these activities.

In addition, for broader dissemination of knowledge gained, all participants were required to present their findings and experiences at a premier conference or publish them in a journal. Through technical guidance, five papers have been accepted for publication at two international en-

(a) Semi-autonomous Tour-guide Robot



(b) Autonomous Waste Sorter



(c) Sensors Fabricated for Unmanned Vehicles

(d) Tele-operation Robot Testing Different Alignments

Figure 1. Prototype of Projects

gineering education conferences, and two poster presentation sessions have also been delivered for the Michigan Science Teachers Association annual meeting [29-33].

Participant Reflections

In-service and Pre-service Teachers

IST participants were recruited from local Intermediate School Districts (ISD) in the following rural Michigan counties: Clare, Gladwin, Gratiot, Isabella, Iona and Montcalm. PST participants, on the other hand, were recruited from the highly renowned teacher education program at CMU. All IST and PST applicants were required to submit an application packet with the following information: 1) professional statement addressing their career goals and expectations regarding the project; 2) career milestones; 3) active participation in student science activities such as science fairs; 4) teaching and research awards received; 5) previous related experience; 6) courses taught; 7) grade point average for PSTs; and, 8) name and contact information of two references. From the applications received, the RET administrators recruited all participants through a rigorous selection process. Criteria used to select the participants included skills or attitude towards teamwork, motivation for professional development, evidence of knowledge in science and education, willingness to share the knowledge at their home schools through instructional resources, geographic diversity, and support from the participants' home institution.

From the numerous applications received, seven ISTs and five PSTs were selected for participation during the first year of the RET program. Overall, the following summary statistics were found for all participants:

- 7 (58%) IST, 5 (42%) PST
- 12 (100%) Whites
- 8 (67%) Males and 4 (33%) Females

The classroom teaching experience of ISTs ranged from 4 to 19 years, where they had taught a range of high school subjects including, but not limited to, physics, physical science, chemistry, mathematics, wildlife agriscience, biology, biotechnology, anatomy, geology and environmental science. All of the IST participants had a college degree in science or mathematics. In addition, the amount of STEM-related professional development activities they were involved in over the past three years varied from 80 to 250 hours. Some of them had master's degrees in education technology or sciences. A few also had several years' worth of industry experience. As all PST participants were students pursuing teacher-education programs in Integrated Sciences, most participants were recruited from CMU (one student was from Western Michigan University) during the first year of offering the RET program. The amount of STEM-related professional development activities they were involved in over the past three years varied from 10 hours to 150 days.

To evaluate the program goals, participants (ISTs and PSTs) were asked about their experiences during the program. The questions and their respective responses are categorized in the following manner:

1) Were you able to establish a relationship with a university faculty member, CEIE to assist in improving your teaching and interpersonal abilities?
   - Learned new approaches in pedagogy through collaboration
   - Gained networking opportunities
2) Were you able to engage in meaningful STEM-based research projects and understand the research process behind them?
   - Gained exposure to engineering product development
   - Challenges in engineering research
3) Did you gain new skills that would help in the development of STEM-based classroom instructional materials?
   - Learned ways to incorporate engineering into the high school classroom
   - Exposure to clear expectations from a high school teacher

Paraphrased sample responses and feedback obtained from ISTs are presented in Table 1, demonstrating that they had increased their network by establishing relationships with fellow educators, were able to engage in STEM-based research and appreciate the intricacies behind it, and primarily gain new technical skills that foster their ability to improve the STEM-based curricula in their respective high schools. Similarly, paraphrased sample responses and feedback obtained from PSTs are presented in Table 2, demonstrating that they had learned the challenges faced by practicing teachers and engineers, gained an understanding of engineering research and, most importantly, feel more prepared to teach engineering to high school students and encourage them to pursue engineering as a career.

Table 1. Paraphrased Reflections of In-service Teachers

Question	Reflections
1	• Learned a lot • Learned new approaches to manage my class as well as my life as a teacher • Networking with fellow teachers, and working together to learn and solve technical problems • Gained an appreciation for the hard work of the design team behind the technological advancements
2	• Learned the engineering design process, and how to integrated the same into classroom • Was able to conduct research and enhance technical skills • Learned the intricacies in engineering research
3	• How to integrate scientific research elements into middle and high school classroom • How to incorporate engineering design process into my classroom curriculum • Gained new ideas to promote engineering in high school classroom

Undergraduate Engineering Students

The rationale behind involving undergraduate ESs in this project was based on two factors: assist the ISTs and PSTs in conducting engineering research and engage them in engineering research through teamwork [34]. Reflections of IST and PST participants clearly show that ES were able to successfully assist them in conducting engineering research. In order to assess how participation in this program helped these engineering students, the following questions were asked: 1) Were you able to engage in engineering research projects and gain an understanding of the process behind them; 2) Did you develop any new skills that would help in your education; and, 3) Did this program nourish your motivation to pursue further research? Feedback obtained from the undergraduate ESs demonstrated that, through teamwork, they were able to conceptualize an idea, identify the problem and solve it accordingly. Most importantly, undergraduate ES feel more prepared in solving problems.

Table 2. Paraphrased Reflections of Pre-service Teachers

Question	Reflections
1	• Able to better plan my future in classroom teaching • Gained networking opportunities with ISTs for potential collaboration in the future • Learned new teaching strategies for effective student learning • Learned how to solve problems from an engineering stand point
2	• Gained exposure and appreciation for intricacies involved in engineering research • Learned the engineering design process, and how to incorporate it into K-12 curriculum
3	• Gained familiarity with NGGS and an exposure to what will be expected from school teachers in the near future • More prepared to teach engineering process and encourage students to pursue engineering as a career choice • Gained technical knowledge that would help me design engineering based lessons in middle and high school curriculum

Program Assessment

With the primary goals of establishing a collaborative partnership, providing a STEM-based platform for science teachers and facilitating the development of high school classroom instructional resources, it is crucial to focus on continuous improvement. Accordingly, prior to the beginning of the RET program, a pre-survey was conducted. Some of the aspects assessed during this pre-survey were reasons for participation, expected benefits, expected challenges, perceived benefit for high school students and their perceptions on science and engineering principles, as presented in Tables 3-7.

For the most common reasons to participate, the majority of ISTs stated that opportunities to learn and participate in engineering research and to design new lesson plans were the primary reasons, while PSTs stated that networking and professional development were the primary reasons. While there was a difference in reasons to participate, it is clear that the program could serve not only practicing teachers, but also prospective school teachers. Given the expected benefits from the ISTs having prior teaching experience, their responses focused more on making connections between their experiences and NGSS, updating lessons plans, implementing the same in their classroom and less on networking. Due to the limited teaching experience of PSTs, their responses focused more on learning about engineering, networking and learning from experienced teachers. Undergraduate ESs, the support personnel in this program, gained opportunities to enhance research skills, while at the same time learn about different engineering perspectives.

Table 3. Pre-survey Reasons for Participation

Reasons for Participation	IST	PST	ES
	No.	No.	No.
Opportunity to engage in engineering research	2	-	2
Learn how to teach engineering concepts	2	2	-
Network with fellow educators with similar interests	-	2	1
Learn new teaching strategies	2	2	-
Gain an edge on my resume or job search	-	2	-
Learning experience	2	1	3
Others (Financial, NGGS)	3	1	1

Table 4. Pre-Survey-Expected Benefits

Expected Benefits	IST	PST	ES
	No.	No.	No.
Enhance research skills	-	-	5
Implementation of engineering into my curriculum or classroom	4	1	-
Updated lessons based on NGGS	3	1	-
Gain exposure to engineering and related challenges	2	5	2
Learn effective teaching strategies	-	2	-
Networking	-	2	-
Others	-	1	1

Table 5. Pre-survey of Expected Challenges

Expected Challenges	IST	PST	ES
	No.	No.	No.
Limited exposure to engineering research	3	3	2
Working with teachers	-	-	3
Translate engineering research into high school curriculum	-	2	-
Others (Lack of funding, not sure)	4	1	1

Table 6. Pre-survey of Expected Benefits for High School Students

Ways This Program Will Benefit High School Students	IST	PST	ES
	No.	No.	No.
Prepare them for future careers and college	3	2	4
They will benefit from a well-informed teacher	-	4	-
It will expose them to engineering concepts	3	1	2
Others	2	-	-

Given the expected challenges, all participants stated that unfamiliarity with engineering concepts and research was the primary challenge. Due to their limited classroom teaching experience, the PSTs also stated that finding ways to incorporate engineering into their respective classrooms might also be a challenge, which is answered through the post academic year support provided by the CEIE coaches. When asked how their participation in this program would benefit high school students, both ISTs and PSTs stated that this program would provide them with information and knowledge that would be shared with high school students, resulting in their being more prepared for future careers and college. In addition, ISTs stated that the new instructional resources developed from this program might help expose high school students to engineering practice and research, while PSTs stated that the professional development experience provided by this program would prepare them to be well-informed teachers.

Table 7. Questions on Pre-survey of Perceptions of Science and Engineering

No.	Question
1	You have to study engineering for a long time before you see how useful it is
2	Memorization plays a central role in learning basic science, math, and engineering concepts
3	A lot of things in science must be simply accepted as true and remembered
4	It is important to teach students how to think and communicate scientifically
5	Every student should feel that science is something he/she can do
6	Every student should feel that engineering is something he/she can do
7	I understand science concepts well enough to be effective in teaching them
8	I understand engineering concepts well enough to be effective in teaching them
9	I am typically able to answer students' questions related to science
10	I am typically able to answer students' questions related to engineering

In addition, all participants were asked to rate the degree to which they agreed or disagreed with ten statements about science and engineering, as presented in Table 7. The first three questions were related to participant perceptions of the nature of engineering, science and/or mathematics. The next three questions were related to participant perceptions of the students (or of what students should be expected to do). The last four questions were related to assessing the confidence level of participants. Results obtained from these questions are presented in Figure 2. While the responses of all groups were similar in aspects such as developing significance of science and engineering in students through a can-do attitude, and effective communication, there were some aspects where they differed statistically. For instance, while ISTs stated that they had an in-depth understanding of science concepts to be effective in teaching them and answering students' questions, PSTs stated that they do not. However, when it comes to engineering concepts, ISTs stated they had a mediocre understanding, while the PSTs stated they had very little understanding in order to teach engineering and answer students' questions, demonstrating the need for more engineering experiences.

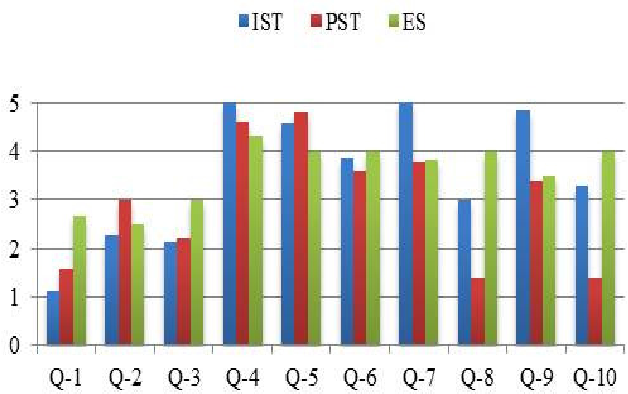


Figure 2. Responses from Participants for the Pre-survey of Perceptions on Science and Engineering

During the last week of the RET program, a post-survey with the following questions was conducted in order to evaluate whether or not the program goals were met: i) Could ISTs and PSTs engage in an engineering research project; ii) Did ISTs gain skills to develop high-school-level instructional materials based on the research experience; iii) Did this program positively affect ISTs' and PSTs' opinions and attitudes towards engineering; iv) How do ISTs and PSTs develop as scientific researchers when immersed in a research project; and, v) How well do ISTs and PSTs understand the research process after participation in this program?

Based on the self-reported scores, it was found that ISTs and PSTs were able to successfully engage in an engineering research project, and were able to convey basic engineering concepts through their respective research projects. In addition, a few stated that they learned the overarching concepts of engineering approaches and problem solving, demonstrating our successful attempts to engage participants in research. Regarding the development of skills, the majority of the participants stated that this program helped develop their skills, abilities and attitudes related to curriculum development and assessment. Furthermore, participants were asked if the professional development sessions on effective teaching were helpful. For this, while the PSTs stated that these sessions were very helpful, there was a mixed response from ISTs. This diverse response from ISTs might be attributed to the different teaching experiences and prior participation in similar projects ahead of time. While a few ISTs stated that information in these sessions was not new, they all agreed that it was a good refresher.

When asked about the effect on the teachers' opinions and attitudes towards engineering, the majority stated that the program had successfully engaged them in engineering research projects, facilitating the development of high school STEM-based classroom instructional materials. In addition, the majority of the participants stated they would redesign lessons and projects, or implement new lessons and projects, based on what they had learned, and that they were equipped to teach engineering principles in high school classes. As these participants were working with CEIE staff (during the academic year) in order to design and implement engineering-based instructional material, further evaluation on this aspect will be done at the end of the academic year.

In addition, to evaluate how well participants understood the research process and developed as scientific researchers, reflection sessions were included during weekly activities. These sessions were tailored for participants to share information on their learning experiences and how they planned to incorporate the same in their high school classroom teaching. During these sessions, faculty observed that participants gained an understanding of scientific research, core engineering skills, and primarily learned the intricacies behind engineering research. Overall, participants rated this reflection session as very useful. Furthermore, to broadly disseminate the knowledge and skills that the participants gained, they were required to present their work at a premier conference or publish in a journal; four papers have thus far been accepted for publication at two international engineering education conferences, and two poster presentation sessions have been planned for the Michigan Science Teachers Association annual meeting.

Overall, the pilot CMU–NSF RET program was successful in meeting the goals set forth for all in-service and PST. Though all participants (ISTs and PSTs) worked in teams on the same project, the learning experience of each was different. The unique strength of each group (IST-teaching experience, PST-enthusiasm to learn, exposure to new technology) complimented the limitation of the other, leading to an effective learning experience and, thus, successfully realizing the program goals.

Lessons Learned and Future Directions

Alongside the pilot implementation of the CMU–NSF RET program in the summer of 2012, and conducting program assessment, the engineering faculty learned several lessons that could be of potential use to other engineering educators considering a similar program. As the School of Engineering and Technology at CMU offers only undergraduate degrees, it has to be noted that these lessons are feedback from the engineering faculty, who usually work solely with undergraduate students.

Lesson 1: An RET program can help cultivate a research culture in an undergraduate institution.

The CMU engineering faculty are actively engaged in personal and undergraduate research, but have struggled in the past to maintain a research culture in the building, especially during the summer months. Pilot implementation of the RET program generated an atmosphere of scholarly activity as experienced by program participants, students and faculty. During the course of the RET program, faculty reported that they were able to advance their research, train their research assistants and improve their leadership and management skills, thus gaining the momentum required to sustain research progress in the semesters to follow. Administration and faculty from other departments witnessed this nurturing atmosphere and provided positive feedback during the poster session at end of the program. Overall, the RET program can be a useful tool for stimulating scholarly excitement in departments where opportunities for scholarly activity are limited.

Lesson 2: RET projects must be carefully designed for a mix of backgrounds.

As initially anticipated, the ISTs did not have the engineering background necessary for conducting advanced engineering design or analysis. However, the engineering faculty was pleasantly surprised with the motivation of ISTs, who were very studious in accomplishing the goals compared to undergraduate students. These ISTs came with a "Show me what to do; I'm ready to get involved!" attitude which is less common in engineering students. Accordingly, the RET projects with significant focus on engineering research, design and analysis were not as successful as projects with limited research and analysis (conducted by the ES and faculty members) and more hands-on activities (conducted by ISTs and PSTs). For instance, the teleoperation project involved integrating the robot and interface, writing the control code and designing the human-based experiment, which were primarily accomplished by the engineering faculty and students, and the ISTs and PSTs focused on proctoring the experiments and analyzing the results. In a broad sense, engineering research and engineering implementation projects worked better than engineering design projects.

Lesson 3: Significant preparation is needed prior to the RET weeks.

During the program, all engineering faculty stated that they should have done more preparation prior to the start of the RET program. This limited preparation can be attributed to several factors such as the short time span between the initial RET award notification and program implementation, limited exposure to knowledge and capabilities of ISTs and PSTs, and a lack of graduate students. As the research goals had to be accomplished during the six-week period, the next time this program is offered, the engineering faculty intends to initiate preparation work the month before by training the ES. Also, since the majority of the preparation is design related or technical in nature, and we learned (lesson 2) that ISTs have limited success in design-related activities, this initial preparation work might assist in accomplishing the research goals set forth. In addition, faculty members also plan to set clear expectations and requirements for all participants, and provide background reading material prior to the beginning of the program so that participants can better allocate their time to conduct quality research work.

Lesson 4: An RET program requires a significant time commitment from the faculty or graduate students under the faculty.

The RET program was beneficial for the engineering faculty as it encouraged their research, encouraged them as they saw teachers and students getting excited about engineering, and produced useful research results. But it was also time intensive; in many cases, unexpectedly so. The engineering faculty spent a significant amount of time advising the teachers and students, and often did the design and technical work themselves. Much of this was due to the lack of a graduate program; but even with a graduate program, someone (faculty or graduate student) will need to spend time designing the project, preparing the background materials, setting expectations, directing the students and teachers and disseminating results. The project will have limited success without this effort. Overall, while this program is a good platform to cultivate a research culture in an undergraduate-program-focused institution, it requires a significant time commitment from participating faculty and their respective students.

Based on the results and lessons learned from the pilot program, the following changes are planned for next year:

1. Applications: All participants will be required to draft a personal statement of expectations from this project. This would help the administration identify candidates that would benefit the most from this program. In addition, advertisements will be sent to ISD late in the fall semester in order to encourage broader participation.
2. Project teams: Engineering faculty members will meet early in the spring semester to discuss the projects and set the expectations and goals. Engineering undergraduate students will be notified in advance

and will be asked to initiate the research project in early summer.

3. Lesson plans: All participants will be required to design a unit lesson plan (4-5 hours long for their respective high school classes) during the coaching sessions in the summer, and present it to other participants and faculty members for potential adoption in the same academic year.
4. Conference proceedings: To encourage broader dissemination of knowledge gained and lessons learned, all participants will be required to identify a conference they intend to attend and draft the conference prior to completion of the summer program with guidance from the engineering faculty member.

Conclusion

The pilot implementation of CMU–NSF RET program at CMU proved to be an effective professional development program for both in-service and pre-service teachers. Based on the feedback obtained during the program, it could be stated that the RET program was effective for engaging teachers in meaningful engineering research experiences that allowed them to gain exposure to engineering concepts and the processes behind them. Participants were able to contribute to the overall research goals and were able to complete a small research project. This learning experience, combined with the post academic year coaching, helped them enhance their respective high school classroom curriculum. The overall combination of research and professional coaching sessions created a highly effective professional development program for high school teachers, thus contributing to the enhancement of K-12 education.

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References

[1] President's Council of Advisors on Science and Technology. (2010). *Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future*.

[2] National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.

[3] Kimmel, H., Carpinelli, J., Burr-Alexander, L., & Rockland, R. (2006). Bringing Engineering into K-12 Schools: A Problem Looking for Solutions, *American Society for Engineering Education Annual Conference & Exposition*.

[4] Guskey, T. (1986). Staff Development and the Process of Teacher Change. *Educational Researcher*, *15*, 5-12.

[5] Joyce, B., & Showers, B. (1988). *Student Achievement through Staff Development*. Longman.

[6] Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What Makes Professional Development Effective? Results from a National Sample of Teachers. *American Educational Research Journal*, *38*(4), 915-945.

[7] Bransford, J., Brown, A., & Cockings, R. (2000). *How People Learn: Brain, Mind, Experience, and School*. National Academy Press.

[8] Yoon, K. S., Garet, M., Birman, B., & Jacobson, R. (2006). The Effects of Mathematics and Science Professional Development on Teachers' Instructional Practice: Using Professional Development Activity Log, *Council of Chief State School Officers,* Washington, DC.

[9] Klein-Gardner, S. S., & Spolarich, A. C. (2011). Impacts of the Vanderbilt University Research Experience for Teachers Program 2008-2010: Analysis of Student Surveys Regarding Motivational Impact, *American Society for Engineering Education Annual Conference & Exposition*.

[10] Klein, S. S. (2009). Effective STEM Professional Development: A Biomedical Engineering RET Site Project. *International Journal of Engineering Education*, *25*(3), 523-533.

[11] Conrad, L., Conrad, E., & Auerback, J. (2007). The Development, Implementation and Assessment of an Engineering Research Experience for Physics Teachers, *American Society for Engineering Education Annual Conference & Exposition*.

[12] Autenrieth, R., Butler-Purry, K., Page, C., Hurtado, L.D., & Welch, J. (2009). Enrichment Experiences in Engineering (E3) for Teachers Summer Research Program, *American Society for Engineering Education Annual Conference & Exposition*.

[13] Choate, L. D., Hatipoglu, K., Fidan, I., & Abdelrahman, M. (2011). RET Project in Additive Manufacturing, *American Society for Engineering Education Annual Conference & Exposition*.

[14] Landis, A. E., Schunn, C. D., Rothermel, M. C., Shrake, S., & Niblick, B. (2011). Development of a High School Engineering Research Program: Findings from a Research Experience for Teachers (RET)

Site, *American Society for Engineering Education Annual Conference & Exposition*.
[15] Kapila, V. (2010). Research Experience for Teachers Site: A Professional Development Project for Teachers, *American Society for Engineering Education Annual Conference & Exposition*.
[16] Benson, L., Medders, E., & Cass, C. (2010). Teachers as Scientists: A Qualitative Study of Outcomes for an RET Program, *American Society for Engineering Education Annual Conference & Exposition*.
[17] Carpinello, J. (2011). Translating Research Experiences into Classroom Practice: An RET Project, *American Society for Engineering Education Annual Conference & Exposition*.
[18] Vallas, C. A., & Trail, J. J. (2011). RET Program Yields Elementary, Middle, and High School Teaching Innovations, *American Society for Engineering Education Annual Conference & Exposition*.
[19] Medders, E. G., Cass, C. P., & Bensonn, L. C. (2010). Development of Teachers as Scientists in a Research Experiences for Teachers Program, *National Association for Research in Science Teaching*.
[20] Directorate of Engineering. (2012). Research Experiences for Teachers (RET) in Engineering and Computer Science, *National Science Foundation*.
[21] DeJong, B. P., & Langenderfer, J. E. (2012). First-Year Engineering Students in Newly Accredited Programs: Enrollment and Persistence Demographics. *International Journal of Engineering Education*, *28* (3), 534-544.
[22] Yelamarthi, K. (2012). RFID-Based Interdisciplinary Educational Platform to Improve the Engineering and Technology Curriculums. *Journal of STEM Education: Innovations and Research*, *13*(5), 46-51.
[23] Yelamarthi, K., Sherbrook, S., Beckwith, J., Williams, M., & Lefief, R. (2012). An RFID based Semi-Autonomous Indoor Tour Guide Robot, *IEEE International Midwest Symposium on Circuits and Systems*, 562-565.
[24] Beckwith, J., Sherbrook, S., Lefief, R., Williams, M., & Yelamarthi, K. (2012). CATE: An Indoor Tour Guide Robot. *IEEE International Conference on Electro/Information Technology*.
[25] Hudspeth, M., & Kaya, T. (2012). Collagen as Dielectric Humidity Sensing Material. *Material Research Society Spring Meeting*.
[26] Hudspeth, M., & Kaya, T. (2012). MEMS Capacitive Relative Humidity Sensor Design, Fabrication, and Characterization, *2nd International Advances in Applied Physics and Materials Science Congress*.
[27] Cai, S., & Zhao, Y., (2010). Design Project Based Modules to Promote Engineering Learning and Retention. *Technology Interface International Journal*, *11*(1), 21-25.
[28] Dischino, M., DeLaura, J.A., Donnelly, J., Massa, N. A., & Hanes, F., (2011). Increasing the STEM Pipeline Through Problem-Based Learning. *Technology Interface International Journal*, *12*(1), 21-29.
[29] Maison, S. H., Bauer, A. J. P., Shapardanis, S., White, T. W., Zhang, Z., Li, B., et al. (2013). Cell Di-Electrorotation: Studying of Rotation to Characterize Biological Cells and the Connections in Engineering to the Next Generation Standards. *American Society of Engineering Education National Meeting*.
[30] Arnold, L., Zhang, Z., Kaya, T., Li, B., & Hu, Q. (2013). Incorporating Engineering into the High School Chemistry Classroom. *American Society of Engineering Education National Meeting*.
[31] Kaya, T., Yelamarthi, K., DeJong, B., Hu, Q., Cheng, S., & Chen, D. (2013). Learned Lessons from the First Year Research Experiences for Teachers Program. *American Society of Engineering Education National Meeting*.
[31] Koch, J., Hancock, J. B., Pang, F., & Chen, D. (2013). Research Experience for Teachers: LEGO MINDSTORM Waste Sorter. *Hawaii International Conference on Education*.
[33] DeJong, B., Duthie, M., Hazen, J., & Jurek, A. (2013). Mental Stress of Camera Viewpoints for Teleoperation- Research Experiences for Teachers. *Hawaii International Conference on Education*
[34] Stanley, D. L., Sterkenburg, R., & Lopp, D., (2011). Undergraduate Student Participation in Applications-Based Research. *Technology Interface International Journal*, *12*(1), 54-59.

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EXPERIMENTAL VEHICLES PROGRAM RESEARCH AND INNOVATION PREPARES STUDENTS FOR CHALLENGES OF TOMORROW

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Abstract

The Experimental Vehicles Program (EVP) in the Engineering Technology Department at Middle Tennessee State University (MTSU) promotes innovative thinking through applied research projects. The rising demand for inventive technology has had a strong influence on modern national and international engineering technology curricula over the past several years. Competent, innovative engineers are needed now more than ever to help solve some of the most complicated problems in the advancement of the engineering technology industry. The various projects of the EVP allow engineering technology students to apply their innovative ideas and classroom knowledge to real-world problems. Projects such as the Moonbuggy and Solar Boat supply a creative environment for nurturing and inspiring innovative thinking, which allows students to generate groundbreaking technologies such as the carbon-fiber structure used in the Moonbuggy. These projects also provide invaluable experiences that give EVP students a competitive edge in the job market upon graduation.

Middle Tennessee State University engineering technology students must function together as a team to design, build, test, promote and race each vehicle in national and international competitions. The teams also disseminate their knowledge to the local middle and high schools to promote interest in engineering technology. The students take their completed vehicles to local schools to raise awareness of the program as well as the possibilities of what a future could hold when entering into a scientific, technological or engineering technology field. The innovative projects have increased interest in engineering technology, incorporated classroom learning into hands-on experiences, and fostered an atmosphere of peer-led team learning, which has benefited the students both personally by improving their interpersonal and career skill sets and academically by providing hands-on engineering technology experiences.

Introduction

The Experimental Vehicles Program (EVP) was created in 2004 as an extracurricular umbrella program for five different undergraduate experimental vehicles including the Solar Vehicle, Moonbuggy, Baja SAE, Formula SAE and Solar Boat. Each EVP project is comprised of a team of students from various Science, Technology, Engineering, and Mathematics (STEM) disciplines throughout the university. Each project team, made up of approximately twenty to thirty students each, works to design, construct and test novel vehicle designs for participation in annual national and international competitions. The undergraduate design teams, which collectively form the EVP, are offered at various universities nationwide. However, the combination of all five design teams under one umbrella program makes the Experimental Vehicles Program at MTSU unique. The consolidation of the five design teams into the EVP improves the sharing of resources and expertise between students and faculty of different backgrounds.

Over the past several years, EVP team members have competed in a variety of national and international events. Each year, the students create a new, increasingly efficient, well-made vehicle for each of the projects. Success at this level not only means winning awards, but it is primarily the reflection of the innovation and dedication of the students. The unique research projects provide great benefits for the professional development of MTSU STEM students. Hands-on learning is a direct application of classroom concepts. In addition, these particular projects help students learn to think innovatively, communicate professionally, manage projects efficiently, and work in a team environment [1]. The competitions are also an opportunity for MTSU students to associate with other students from engineering schools around the country and globe [2]. Although most participants represent engineering and engineering technology majors, students from various disciplines have participated within the program.

Each year, students think creatively to design their blueprints, construct each vehicle from scratch, and enter each project into its respective competition. Each competition is composed of several events, providing a unique set of challenges along with racing against some of the top engineering schools in the nation, including the Georgia Institute of Technology (the 4th-ranked engineering school in the U.S.), the University of Illinois Urbana-Champaign (ranked 5th) and Cornell University (ranked 11th) [3]. Students work diligently on these projects and incorporate skills needed in the workforce such as project management, decision making, leadership, critical analysis and problem solving. EVP participants learn the value of research, teamwork and effective communication. They learn to incorporate innovative ideas into a single goal, complete projects, and excel at competitions. In addition, the national and international design competitions provide valuable exposure for Middle Tennessee State University [2].

Middle Tennessee State University's Solar Boat

Middle Tennessee State University offers several nationally competitive experimental vehicle projects as extracurricular activities for undergraduate STEM students [4], including the Solar Boat project. The Solar Boat project was founded following the inception of the Institute of Electrical and Electronics Engineers Power Electronics Society's Solar Splash Competition, an international collegiate competition showcasing solar/electric boating [5]. The Solar Boat project focuses on the capture, utilization and storage of solar energy to power a special-purpose boat. The boat design must follow a set of regulations to accomplish numerous pre-determined outcomes [6]. Nevertheless, the students are given a large amount of freedom in the design and operation of their Solar Boat. The project culminates at the annual five-day competition, where the students showcase their efforts and compete against other student design teams in various categories [5].

Figure 1. Solar Boat during Competition

The Solar Splash Competition can be classified as a "brain sport," an activity giving STEM students an opportunity to experience real-world design and engineering problems [7]. Students utilize their classroom knowledge of engineering principles while simultaneously developing valuable soft-skills such as teamwork and communication [4]. The overall effect of the project is an enjoyable, educational and engrossing experience for the students, which encourages the exploration and pursuit of engineering technology and solar technology.

The overarching theme of the Solar Boat project is to encourage students to excel in their studies and to get them excited about solar energy. It has been noted that past Solar Boat students became so interested in their projects that they actively pursued careers in the solar and other alternative energy fields. The project provides the fundamental knowledge and hands-on experience valued by employers, and serves to fill in any gaps in understanding from the students' classroom education.

Figure 2. Solar Boat at the Solar Splash Competition

During the Solar Boat project, students are faced with challenging dilemmas that are best solved through creative problem solving. For example, the 2012 Solar Boat incorporated an innovative drivetrain system. The drive system provides adjustable trim, while simultaneously facilitating rudderless steering. This groundbreaking steering integrates interchangeable motors, transom-mounted surface drive, interchangeable sprockets for variable gear ratios and surface-piercing propellers. This type of innovative drivetrain had never before been attempted at MTSU.

The Solar Boat project provides a creative outlet for engineering technology and other STEM students. The peer-led environment provides a congenial and supportive network, while the project itself begs for clever and imaginative approaches. Solar technology provides a plethora of challenges in its capture and utilization and, when applied to its application in a vehicle, gives the students a foundation on which to focus their efforts.

Figure 3. MTSU Student-designed Innovative Drivetrain

Students are often awarded for their creativity at the annual competition, where certain aspects of the Solar Boat, such as most outstanding hull design, are duly recognized and rewarded. Creativity must be supported and cultivated among students of engineering technology, as they are not as restrained by conceptual barriers that may cloud the mind of an experienced engineer [4]. The future success of solar energy will no doubt be the product of a collection of unconventional "outside-the-box" ideas generated by a new generation of inventive engineers.

Figure 4. Blue Raider Solar Boat Team

The Solar Boat project takes engineering technology students beyond classroom learning. Though students may amass a large amount of knowledge in the classroom and feel confident in their abilities prior to graduation, they could feel overwhelmed once entering the workforce, deterring them from remaining in an engineering field. Difficult or seemingly esoteric concepts can be made clear through direct application or visualization via a hands-on undergraduate engineering project. Through the active development of the Solar Boat, students gain appreciation for the development of a design from the concept and cost-analysis phases through final production. The students learn how to respect both ergonomic and equipment restraints—a fundamental consideration for all practicing engineers. However, they also work in an environment that encourages the freedom to develop alternatives to the given challenges. Solar energy is a field full of potential and unexplored avenues, and students on the Solar Boat Team are given a unique perspective on the issue and are motivated to design something new and different. These students are less likely to conform to textbook solutions when exposed to similar challenges upon entering the workforce [4].

Moonbuggy

The Moonbuggy project is a versatile vehicle that has inspired MTSU undergraduates to create novel engineering innovations. The Moonbuggy is designed to be a lightweight, compact, flexible and durable all-terrain vehicle. According to the NASA-sponsored Great Moonbuggy Race rules, the vehicle must be human powered and controlled by one male and one female student over a half-mile simulated lunar terrain, full blown with craters, lava ridges, rocks, inclines and lunar soil. The vehicles are judged on the performance over the terrain and the overall design. Students involved in the project each year work diligently to incorporate new and innovative designs to enhance the performance of the Moonbuggy over the lunar topography. Brainstorming prior to the fabrication of the vehicle has led to exciting inventive breakthroughs such as the carbon-fiber frame. This material is ideal for a lunar vehicle, due to its exceptional strength-to-weight ratio that allows easy maneuverability in a low-gravity atmosphere.

Between 80% and 90% of all vehicle fabrication and assembly is carried out in MTSU's Voorhies Industrial Studies Complex in a dedicated workspace. Every year, students pay close attention to the wheels of the vehicle, fabricating them entirely in the engineering laboratories at MTSU. Some of the most innovative discoveries by the EVP students came a few years ago when the wheels were constructed from 1/2" aluminum stock and measured twenty-one inches in diameter, with a 2.5" tire. The design consisted of six identical sections bolted to a central aluminum plate. The spokes were made on a CNC machine from a design that eliminated the imminent strength problems that most teams encounter with classic bicycle spokes. The spokes increased the strength of the wheels but allowed for the replacement of only the affected part in the event of damage.

Figure 5. Revolutionary Aluminum Stock Wheel

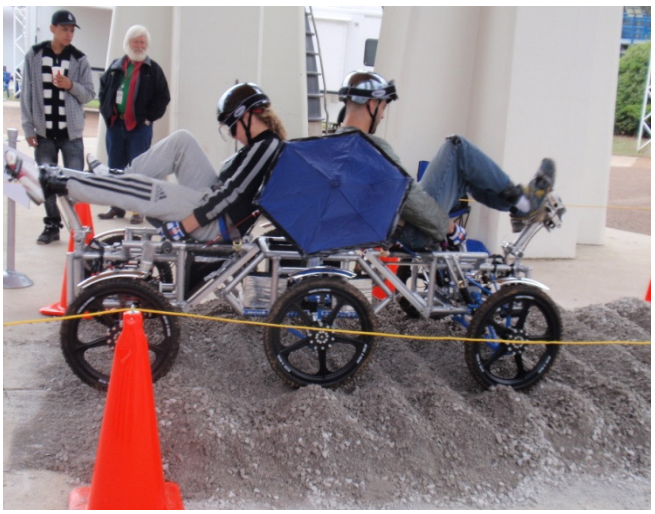

Figure 6. Six-wheeled Moonbuggy during Competition

Last year's Moonbuggy team took thinking outside of the box to a new level when they designed a competition vehicle containing six wheels instead of the usual four. This groundbreaking vehicle design was the first of its kind to be used in the Moonbuggy competition. The six-wheel design allowed the vehicle to be streamlined; the vehicle was able to maneuver around the competition course with incredible flexibility and speed.

Program Implications

Retention and Graduation

The aim of all collegiate engineering technology programs is to produce sophisticated and talented engineers who are ready to enter the workforce upon graduation. Many students may leave the engineering discipline or choose not to pursue such a career because they lack confidence in their knowledge and abilities, namely in mathematics and science. The EVP projects seek to encourage students to put their hands on an actual project and gain experience regardless of their opinion of their engineering skills. At the beginning of the project there is no right or wrong solution, and students of all backgrounds and skill levels combine their ideas as they work towards a common goal. The learning objective of such a project is to test out a variety of theories and methods and to investigate the consequences of each decision. Mistakes are seen as learning opportunities for the future. Even if a student lacked confidence in his or her abilities as an engineer, such hands-on experiences are often the spark that fires the creative imagination that causes the student to become fascinated with solar energy and the future of alternative fuel, making him or her more likely to continue studying engineering and engineering technology.

The introduction of hands-on, experiential learning projects aimed towards engineering technology and STEM students can provide them with a solid environment in which to build confidence as they hone their professional skills. Projects which focus on a major societal crisis such as solar energy can further encourage the students to explore a novel and critically important field of technology [8]. The benefits of such solar-focused engineering technology projects are two-fold: 1) students are encouraged to study engineering technology, and 2) they become intimately involved with the specialized technology, making them more attractive to potential employers upon graduation.

While the Solar Boat and Moonbuggy projects have been a major cornerstone in getting students involved and interested in engineering technology, they have also been key players in retention and recruitment that the EVP also prides itself on. Current estimates report that less than five percent of college-bound high school seniors are interested in pursuing a degree in engineering [9]. Of the relatively few students who begin their college career in engineering technology, many will abandon the field of study. While it is difficult to pinpoint exactly what motivates students to leave their engineering technology studies, it is important to note that engineering technology disciplines are often regarded as the most difficult category of majors at the collegiate level. Due to the engineering technology discipline's reputation for being extremely challenging, it is vital for engineering technology educators to take action to improve enrollment and retention rates through the implementation of unique student projects and programs [10].

Middle Tennessee State University's Experimental Vehicle Program's projects are just one example of a valuable teaching tool that has been utilized to target enrollment and retention issues with proven success since 2005 [11]. The first major retention issue that projects target is the lack of a well-defined student support system. Numerous studies have shown that students who are involved in small groups retain more than students who work alone [12]. Isolation of a student from his or her peers can cause stress beyond that imposed by an already formidable field of study. At the beginning of each school year, the Solar Boat and Moonbuggy projects fall under the responsibility of a group of students who opt to become members of the University's EVP Team. Students from any background and major are invited to attend, though historically teams have primarily consisted of students from the Engineering Technology department. All EVP teams are primarily student-led, with assistance provided by the faculty advisor and numerous university staff members. Team organization and operation relies on a modified and proven Peer-led, Team-learning (PL-TL) model [11,12,13], where students support and mentor each other throughout the course of the project.

The PL-TL model is designed to supplement classroom lectures by requiring students to engage in active group learning. The group environment can prove more conducive to learning than a classroom setting, as the students feel less pressure to provide correct answers or "textbook solutions" to the problem at hand [13]. The benefits of group activities to STEM-student retention have been well-documented. A study conducted by Tinto [14], [15] reported that student involvement in group learning environments promoted student retention. Tinto writes that "For some students…the collaborative environment of the learning community provided a safe place, a smaller knowable place of belonging, in which they were valued and in which they discovered they could learn."

The Solar Boat Team members as well as the Moonbuggy Team members collaborate on all decisions throughout the lifetime of their annual project. Together, the students brainstorm how they want to build their boat and conduct all of the necessary research, construction and testing in preparation for the annual competition. As per the PL-TL model, the more senior students lead the inexperienced students [6]. The students often develop strong relationships with their teammates, which in turn encourages them to continue the pursuit of the project and their degree. Such academic and social support networks are crucial components of student retention [14].

The second problematic issue that all EVP projects seek to mitigate is the suppression of creativity and ingenuity. Often in STEM disciplines, much value is placed on achieving single, correct answers with no additional credit awarded for innovative approaches to problem solving [4]. Students are often discouraged from recognizing or exploring alternative approaches to problems. The fear of being wrong or labeled as "unusual" can lead to excessive reliance on stilted or rote problem-solving skills [4], which may likely discourage some students from remaining in or entering the engineering technology field. Conventional and uncreative behavior is directly counter to the qualities desired of future innovators, especially those expected to tackle some of the most important engineering technology issues ever encountered in modern human history.

Student Outcomes

One of the main goals of the Experimental Vehicles Program is to engage students. Most undergraduates are only exposed to general classroom curricula. However, the EVP provides an outlet that allows students to gain hands-on experience. It also supplies the students with valuable knowledge concerning the process involved in completing complex engineering projects. Due to the fact that the students are peer led, they are able to be involved in every aspect of the vehicle's creation, from conception to design to actual manufacturing. The competition teams are comprised of undergraduate students that are recruited across many disciplines in order to incorporate as much diversity into the program as possible. These students typically represent the STEM concentrations; however, this extracurricular program is open to any discipline. The teams on average are not gender specific and are representative of multiple nationalities. This ensures that the students will be able to learn from collaboration, while at the same time preparing them for a future job in which communication will be the key to being fully understood.

Annually, EVP members are comprised of about 30% females and 70% males. Of these, generally the demographics break down roughly to 50% white, 20% African American with the final 30% made up of other nationalities. Each vehicle team is comprised of approximately twenty students that are split up into smaller teams that will each focus on specific aspects of the vehicle. Each team has constant access to a graduate student mentor as well as faculty advisors. With such a readily available support system, the students are able to explore their skills in ways they may not have been able to before.

Giving undergraduate students the opportunity to gain hands-on experiences through extracurricular lab-based projects has proven to be critical and should be considered as an obligation to all universities [16]. The skill set acquired through the EVP projects at MTSU helps students involved after graduation to secure high level jobs. For those students that get involved in the EVP program as a freshmen or sophomore, and take on leading roles in project design and manufacture, have reported back to EVP faculty that their initial base salary is $20,000-$25,000 more than their contemporaries. Due to the real-world experience, the EVP students report that their employers are paying them as if they have 2-3 years of job experience; this is an incredible edge in the very competitive job market. Past EVP students have been able to procure careers with Nissan, Tennessee Valley Authority (TVA), NASA, GM, and other automotive industries. Moreover, on numerous occasions, the companies that have hired an EVP graduate have contacted EVP faculty mentors asking if any other students are graduating with the same experience and expertise. This is an incredible statement to MTSU, the EVP and its students.

Conclusion

The Experimental Vehicles Program in the Engineering Technology Department at Middle Tennessee State University promotes innovative thinking through applied research projects. These projects are novel and inspirational. They allow students to gain important hands-on experience, while giving then the encouragement to harness their engineering prowess. Classroom discussions have some limitations in the goal of exposing Middle Tennessee State University students to the challenges that they will face in the real world. The Experimental Vehicles Program (EVP) at MTSU is an innovative, award-winning program that supplements classroom discussions and provides students with a forgiving environment in which to test the skills and knowledge they acquire at MTSU.

EVP projects not only enhance classroom learning but also teach students things they ordinarily wouldn't learn in a class, such as organizational, leadership and communication skills. Perhaps most importantly, the projects give students a taste of the engineering team environment, and help foster effective working relationships.

The EVP experience has not only provided a valuable way for MTSU students to gain essential hands-on experience, but also has led to higher retention and graduation rates. In addition, out of the many students that participate in EVP projects, 95% receive highly desired jobs upon graduation. As further testament to the fortitude of this program, the Tennessee Board Regents awarded the program the Academic Excellence Award in 2012. Because of the competitive nature of each event that the EVP participates in, students must use cutting-edge technology and design methods in order to field the very best entry possible. Often, these projects serve as rolling test beds for the latest innovations in various technical fields and are accompanied by a great deal of student research.

References

[1] Foroudastan, S. (2004). *Mechanical Engineering Education: Not Just about the Math*. Reported by IMECE International Mechanical Engineering Congress, Anaheim, CA.

[2] Foroudastan, S, Klapper, R., & Hyde, S. Intercollegiate Design Competitions and Middle Tennessee State University's Machine Shop: Kindling Engineering Technology-Student Creativity & Confidence.

[3] Foroudastan, S. (2007). *Enhancing Undergraduate Education through Innovative, Applied Research Projects*. Reported by ASEE 6th global Colloquium on Engineering Education in Istanbul, Turkey.

[4] Holmes, M. (2011). Brain Sports Find a Place in the Sun. *Society of Women Engineers, Summer*, 14-16.

[5] Grand Challenges for Engineering. (n.d.) Retrieved May 2 2011 from http://www.engineeringchallenges.org/cms/8996/9082.asp

[6] Welcome to Solar Splash. (n.d.) Retrieved May 2 2011 from http://www.solarsplash.com/splash/spl_intro.html.

[7] U.S. News & World Report, L.P. (2009). Rankings: Best Engineering Schools. Retrieved September 21, 2009 from http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-engineeringschools/ranking

[8] Chang, Y. (2011). Vehicle Profile Design versus Solar Energy Collection: Styling Consideration for Solar-powered Personal Commuter Vehicles. *International Journal of Engineering Research & Innovation*, *3*, 15-24.

[9] Foroudastan, S. (2006) *Undergraduate Research and Creative Activity at MTSU*. Reported by ASEE Conference.

[10] Foroudastan, S., & Hulsey, K. (2009). Applied Engineering Stimulates Undergraduate Technology Students Innovative Thinking and Success at National Competitions. *International Journal of Modern Engineering*, *10,* 21-28.

[11] The Case for a Name Change. *A UMR White Paper*. (n.d.) Retrieved November 10, 2006 from http://www.umr.edu/namechang

[12] Foroudastan, S. (2009) *Enhancing Undergraduate Performance through Peer-Led, Team- Learning (PL-TL)*. Reported by ASEE Conference.

[13] Hockings, S. C., DeAngelis, K. J., & Frey, R. F. (2008) Peer-led team learning in general chemistry:

implementation and evaluation. *Journal of Chemical Education*, *85*(7), 990-996.
[14] Tinto, V. (1993). *Leaving college: Rethinking the causes and cures of student attrition*, (2nd ed.). The University of Chicago Press, Chicago.
[15] Tinto, V. (2003, November 5-7). *Promoting student retention through classroom practice.* Presented at Enhancing Student Retention: Using International Policy and Practice. An international conference sponsored by the European Access Network and the Institute for Access Studies at Staffordshire University. Amsterdam Retrieved on 2010, September 8 from http://www.staffs.ac.uk/access-studies/docs/Amster-paperVT(1).pd
[16] Waldrop, P., & Jack, H. (2012) Preparation of Engineering and Technology Graduates for Manufacturing Careers. *International Journal of Engineering Research and Innovation*, *12*, 79-86.

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Comprehensive List of Parameters Affecting Wastewater Pipe Performance

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Abstract

Risk is the combination of likelihood of failure and consequence of failure. Important variables to assess the likelihood of wastewater pipeline should be collected and compiled for use in risk ranking by the water utilities. There are many parameters that affect the performance and failure of wastewater pipeline infrastructure systems. For the purpose of analysis, design or both, it is necessary to develop a complete understanding of all parameters that have an influencing role in wastewater pipeline performance. Having an understanding of the wastewater pipeline parameters and their effects that lead to pipeline deterioration can aid in comprehensive data collection and better asset-management, decision-making processes. Specifically, the parameters can be used in developing a robust condition or performance index, performance prediction model, prioritizing repair and rehabilitation, prioritizing inspection, planning operation and maintenance, developing capital improvement programs and making high-level decisions. This paper summarized the factors that affect the performance of wastewater pipelines. In addition, a complete list of possible collection methods for each of the parameters is provided.

Introduction

A key to implementing an asset management strategy is a comprehensive understanding of pipeline parameters and their effects that lead to pipeline deterioration. The performance of a wastewater pipeline is determined by analyzing the pipes' characteristics, operational factors and external factors. The pipelines used in municipal wastewater systems are made from a variety of materials, depending on suitability of the pipe location and design purposes. Each pipe material undergoes failure in a different way. Failure in wastewater pipes depends greatly on pipe characteristics, the surrounding environment (internal and external) and operational practices.

Wastewater pipe structural and functional deteriorations have an essential role in pipe asset management, capital improvement planning and renewal planning. The reliability of decision-making tools, such as wastewater pipe deterioration and performance models, depends greatly on a comprehensive understanding of wastewater pipe deterioration parameters, condition and performance.

The parameters that affect wastewater pipe structural deterioration, operation and maintenance have been identified through a series of studies [1-25]. The National Association of Sewer Service Companies' (NASSCO's) Pipeline Assessment and Certification Program (PACP) [4] presented a standardized system to evaluate internal television inspections of wastewater collection assets. Visual defects are identified utilizing key structural and operation and maintenance (O&M) parameters. Collection system assessment through PACP, or other similar methods, can then be recorded and evaluated. Szeliga and Simpson [13] and Makar [27] investigated failure modes and mechanisms of pipes. Factors related to structural condition and influences were noted.

Other studies, conducted by NRC-Canada [5], and the U.S. EPA [20] focused on inspection and condition assessment. NRC-Canada presented guidelines for assessing and evaluating wastewater collection systems. It recommended that information on location, physical dimensions, related land-use areas, operating conditions and applicable structural and operational data should be recorded. Condition assessment of pipes in the system should be rated based on structural integrity, functional integrity and hydraulic adequacy. CARE-S [3] was developed by the European Commission with the goal of producing a decision support system (DSS) to maintain effective management of sewer networks. It takes into account all aspects of rehabilitation decisions with a link to Performance Indicators (PI). Al-Barqawi and Zayed [15], Chughtai and Zayed [17] and Kathula [21], and Mehta [23] proposed condition rating models and identified performance indicators of the wastewater pipes. Decision support systems, such as performance prediction models and maintenance optimization tools, proposed by Stone et al. [6] and Nelson et al. [24] identified and utilized wastewater parameters.

However, many studies focused only on specific utilities or areas. Some studies focused mainly on certain subjects and/or parameters, and they did not provide an inclusive overview of wastewater pipe infrastructure performance and deterioration. A complete list of parameters that affect wastewater pipe does not exist. Hence, there is a need for a comprehensive list of the parameters that affect wastewater pipes to support an asset management strategy, renewal decisions and performance evaluation models. Wastewater pipe infrastructure data frequently have been recorded in several cities and in utilities' documents, such as maps, maintenance records, daily field logs, recorded flow data, as-built (or record) drawings, specifications and survey information. Often, the compilation of all wastewater pipe system information fails due to the lack of proper means to store the information so that it can be retrieved and used easily, and the lack of integration among sections or departments in utilities.

An extensive study was conducted in order to provide a dependable list of pipe parameters from the literature, questionnaires and utility and pipe association interviews. The goal is to eventually create an inclusive list of all parameters that affect the deterioration and performance of pipe infrastructure. This paper summarizes wastewater pipe performance parameters and their influences. In addition, a complete list of possible collection methods for each parameter is provided.

Pipe Infrastructure System

Pipelines are major assets of wastewater collection systems. Most buried pipeline networks were installed using open-trench construction methods [26]. This construction method typically consists of placing pipes on bedding material and backfilling the trench. Studies have shown that the structural performance and behavior of the buried pipe is dependent on the type of backfill placed around the pipe, the construction sequence, compaction control, surface loads and the type of pipe material (flexible or rigid) [27-32].

The pipelines used in municipal wastewater systems are made of different types of material depending on the location and design. Commonly, wastewater pipes are made of concrete (reinforced and non-reinforced), clay and PVC, though a small number of metal pipes and brick sewers do exist. Each pipe material fails differently. Rigid pipe is designed to resist external loads by its inherent strength, whereas flexible pipe relies on the capacity of the surrounding soil to carry the load and provide stability. All types of pipe can perform well, but the conditions for satisfactory long-term performance vary. Furthermore, the performance criteria are different for pipe type: the severity of cracking is the main performance criterion for rigid concrete pipe, whereas the degree of deflection is the main performance criterion for flexible pipe. For the purpose of analysis or design or both, it is necessary to develop a complete understanding of the failure modes and mechanisms.

There are many parameters affecting wastewater pipe infrastructure systems and their failure. Examples of these parameters are structural—such as pipe diameter, age and material—and environmental—such as soil properties and external loading. Figure 1 shows some of these parameters which affect pipe deterioration over both the short term and long term. Changes in one parameter will also affect the others. For example, in concrete pipe, excessive loadings along with poor pipe bedding can cause pipe cracks and fractures. Cracks and fractures in the pipeline will cause infiltration and exfiltration.

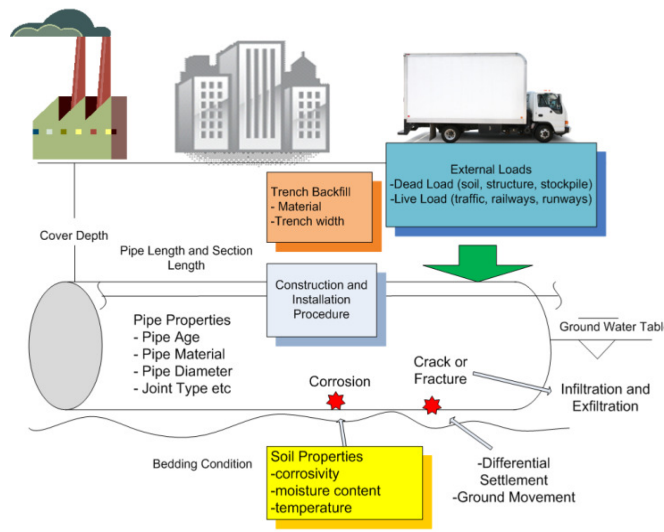

Figure 1. Factors Affecting the Condition and Performance of Buried Pipes

Buried pipes present many challenges:

- Buried pipes are not readily accessible for inspection and defect detection.
- Buried pipes are subject to degradation mechanisms from the outside (soil side) as well as from the inside (fluid side).
- The external environment of buried pipeline has loading, chemical, geotechnical and soil-pipe structural considerations that can be unique to each installation and/or site.
- Pipe bedding materials can also vary by their nature and degree of inspection or verification during the installation process.
- Buried pipes encompass a wide range of materials and a wide range of sizes.
- Buried pipes may be bare or they may have a variety of external coatings and internal linings.
- The design formulas and corresponding design margins for soil and surface loads are not well defined for wastewater buried pipes.

Pipeline Parameters

A comprehensive list of parameters and their influence on pipeline performance for all wastewater pipe materials is presented below in alphabetical order.

A

Age: The length of time since the asset was installed. Age may or may not be a strong indicator of pipeline deterioration and can be a function of the material type and other factors. Typically, it is assumed that older pipes have sustained longer stresses and may be subject to deterioration with age. The unit of this parameter is *year*. This parameter is important for all pipe materials.

B

Backup Flooding: Sewer overflow occurs when the pipe is blocked, which results in backup flooding into building basement or street through inlets and manholes. Usually, backup flooding is catastrophic and may contaminate the environment. The unit of this parameter is *yes/no.* This parameter is important for all pipe materials (see Overflow).

Bedding Condition: A pipe is not made to act as a load-bearing beam and must be supported through adequate bedding. The bedding should be a uniform support made up of clean backfill that is properly tamped to reduced settling and shifting (see Non-Uniform Bedding and Trench Backfill). Uneven support due to lack of proper bedding conditions can lead to beam stress on the pipe [3. The unit of this parameter is *condition level.* This parameter is important for all pipe materials.

Blockage: Blockage makes pipe networks inoperative, and wastewater systems no longer function as designed. Blockage may be caused by unintended objects getting into the system or parts of the broken or collapsed pipe blocking the flow. Smaller diameter pipes are more likely to have a blockage. The units of this parameter are *yes/no* and *condition level.* This parameter is important for all pipe materials.

C

Cathodic Protection: Cathodic protection is a technique used to control the corrosion of a metal surface by adjusting the electric potential of a pipe. The most common protection method is the sacrificial anode method which uses galvanic anodes of zinc and magnesium. In the presence of stray currents, these active metals oxidize more easily that lead to corrosion of the sacrificial anodes and not of the protected metal (see Stray Currents). The active materials must oxidize almost completely before the less-active metal will corrode. This parameter only is applicable for metal pipes. The unit of this parameter is *yes/no.* This parameter is important for metal pipes.

Closeness to Trees: A pipe in close proximity to trees may be subject to root intrusion, if there is a crack or a hole presented in the pipe. Tree roots may also seep through an open or separate joint. The unit of this parameter is *ft*. This parameter is important for all pipe materials.

Coating: An external coating is an approach used to provide protection of the pipeline from external corrosion. If properly applied, a coating can provide resistance to soil corrosivity, hazards of pipeline transportation and fluid penetration or absorption (see Soil Corrosivity). This coating can only be applied during the manufacturing process [3. The unit of this parameter is *yes/no.* This parameter is important for metal pipes.

Condition: Pipe condition can be determined by different types of inspection. Typical inspection methods used to examine pipes are CCTV inspection, smoke test and dye test. The unit of this parameter is *condition scale 1-5*. This parameter is important for all pipe materials.

Connection Density: The required wastewater capacity is dependent on the number of service connections. The pipe size and flow rate of the collection mains must be adequate to transport wastewater to the treatment plants. The unit of this parameter is *number of lateral connection/100ft*. This parameter is important for all pipe materials (see Diameter and Flow Velocity).

Cover Depth: The pipe depth can play a factor in the amount of stress applied to the pipe as a result of live and dead-load loading. As the soil cover increases, the load pressure decreases [5. The amount of cover can also influence the type of failure mode and mechanism. For example, if the pipe is buried at sufficient depth, it is more likely to develop localized buckling than beam buckling [3. A shallow pipe depth may also be a factor for third-party damages. The unit of this parameter is *ft*. This parameter is important for all pipe materials.

D

Design Life: The period of time that the pipe is expected to operationally function. A high design life typically indicates a longer life expectancy; however, other influencing parameters may reduce the expected life. In contrast, the pipe can also be functional past the design life. The unit of this parameter is *year*. This parameter is important for all pipe materials.

Diameter: The diameter of a pipeline is typically classified by the nominal diameter or outside diameter rather than the inside diameter. Small-diameter pipe are more susceptible to beam failure than larger pipe diameters. In relation to pipe capacity, smaller diameters are easy to be blocked by objects, root intrusion or built-up sediment. The unit of this parameter is *inch*. This parameter is important for all pipe materials.

Dissimilar Materials/Metals: When dissimilar metals are connected and exposed to an electrolyte, galvanic corrosion will occur since the metals have different properties. The galvanic difference within the metals causes one metal (anode) to release electrons to another metal (cathode). The metal that discharges the electron can result in pipeline corrosion, while the metal accepting the electron is protected from corrosion [3. The unit of this parameter is *yes/no.* This parameter is important for metal pipes.

Disturbances: Third-party disturbances to the pipeline can lead to direct or indirect damage. For example, construction disturbances due to excavation can lead to direct damage, which results in the equipment physically breaking the pipe or indirect damage due to soil movement close to the pipe. Disturbances in the pipe bedding or alignment can lead to beam failure if the pipe is not adequately supported and/or the pipe depth is not sufficient [3. The unit of this parameter is *yes/no*. This parameter is important for all pipe materials.

E

Exfiltration: Exfiltration refers to wastewater getting out of the system through cracks, holes, separated joints and/or opened joints. Exfiltration may contaminate the surrounding environment and water sources. The unit of this parameter is *level*. This parameter is important for all pipe materials.

Extreme Temperatures: A change in climate can result in stresses that occur to the pipe itself and the soil surrounding the pipe. As a result of hot and cold temperatures, the pipe endures dimensional changes due to the expansion and contraction of the material. These dimensional changes create increased axial loads in the pipe. Furthermore, the soil can create a downward pressure due to the expansion of water freezing within the soil pores during cold temperatures while contracting when the water content is reduced during hot temperatures [3. The unit of this parameter is *degree Fahrenheit*. This parameter is important for vitrified clay pipes.

F

Failing Utilities: Failed utilities located in the vicinity of the wastewater pipeline can result in soil disturbances and possible changes in bedding configuration, ultimately leading to wastewater pipe failure. The unit of this parameter is *yes/no*. This parameter is important for all pipe materials.

FOG: FOG also known as fats, oils and grease. FOG build-up in the system can cause blockage and overflow. The units of this parameter are *yes/no,* and *condition level.* This parameter is important for all pipe materials.

Flooding: Flooding can impact the pipe and soil equilibrium causing the pipe to collapse or float out of alignment. Aggressive waters and/or constant water in contact with the pipe can increase the external corrosion rate [3. The unit of this parameter is *occurrence level*. This parameter is important for all pipe materials.

Flow Velocity: The flow of the fluid through the wastewater pipe. Flow velocity can determine the pipe capacity and required pipe diameter during pipe design. Velocities should not be less than 2 ft/s, which causes sediment to build up. However, excessive velocities are not recommended because they lead to mechanical surface wear and exposure of aggregates in concrete pipes. The unit of this parameter is *ft/s*. This parameter is important for all pipe materials.

Frost Penetration: Frost penetration is the depth to which frost can penetrate the soil. The greater depth of frost penetration increases the earth loading on the pipe. The increase in dead load results in a compressive stress or crushing force which acts on the pipe, leading to potential longitudinal cracks [3. The unit of this parameter is *yes/no*. This parameter is important for all pipe materials.

Function: Different uses of a sewer may deteriorate at different rates. Whether it is a combined sewer, separate sewer or forced main, different parameters are considered in performance evaluation. The unit of this parameter is *type (e.g., gravity sewer, force main).* This parameter is important for all pipe materials.

G

Groundwater Table: The location of the groundwater table can affect the pipe-soil relationship. If the pipe is located at or below the water table, floatation may occur if proper measures are not considered such as a greater soil cover or a weighting system. Constant contact with groundwater may lead to external corrosion in metal pipes [3. The unit of this parameter is *ft*. This parameter is important for metal pipes and reinforced concrete pipes when cracks are present.

H

Hydrogen Sulfide Gas (H_2S): High levels of H_2S concentration can severely cause pipe corrosion and eventually lead to structural failure. Sulfuric acid that corrodes the pipe near the crown is formed by hydrogen sulfide gas in sewage. H_2S usually occurs in shallow-slope pipes. The unit of this parameter is *level* or *ppm*. This parameter is important for metal and concrete pipes.

I

Inflow and Infiltration (I&I): I&I refers to outside water getting into the wastewater system through cracks, holes, separated joints and/or opened joints. I&I may cause surrounding soil erosion and unnecessary increases in flow volume. The unit of this parameter is *condition level* or *Gallon/min*. This parameter is important for all pipe materials.

Installation: Poor installation can result in inadequate bedding and/or possible damage to the pipe itself. Prior to the 1930s, installation specifications required the pipe end bells to be placed on top of solid supports; however, over the years, it was determined that such supports can lead to uneven support and excessive beam stress. Also, the general construction practice consisted of refilling the trench with the excavated soil. Today, practice requires clean backfill to protect the pipe from uneven bedding and reduce the chances of corrosion potential [3. The unit of this parameter is *level*. This parameter is important for all pipe materials.

J

Joint Type: Joints for the various material types have evolved over the century. Today, many of the available joints provide a greater amount of flexibility and versatility. The flexibility of the joint can also compensate for ground movement. Typical joint types for concrete pipe are lined joint, rubber gasket joint and steel endring joint. The unit of this parameter is *type*. This parameter is important for all pipe materials.

L

Lateral: A lateral pipe refers to a small pipe connecting a mainline to a household. If the lateral is not properly connected, I&I can occur. The unit of this parameter is *number of connections*. This parameter is important for all pipe materials.

Length: There are two lengths regarding wastewater pipeline: a section length between joints and a node length between manholes. An increase in pipe section length can lead to increased stresses as a result of differential ground movement transverse to the pipe axis. A pipeline that is not properly supported can result in beam stresses. Excessive beam stress can lead to circumferential cracking [3. A pipe with a node length greater than 500 ft is considered difficult to maintain, due to maintaining the equipment operating length. The unit of this parameter is *ft*. This parameter is important for all pipe materials.

Lining: The internal surface of a pipe can be covered by a coating to improve resistance from tuberculation and corrosion. The lining is also used to prevent inflow/infiltration of water from soil and exfiltration of wastewater into the environment if cracks and fractures are present. This lining can be applied during the manufacturing period or installed to an existing pipe. Common types of linings consist of mortar linings and epoxy coatings. The units of this parameter are *yes/no* and *type*. This parameter is important for all pipe materials.

Live Load: Live loading from traffic can cause compressive forces on the pipe wall. This downward pressure is a factor of the pipe depth, soil type, type of pavement (rigid or flexible) and the type of vehicles (see Cover Depth and Soil Type). Excessive crushing forces can lead to longitudinal cracks on the pipe wall. Bending stresses are also present within the pipe if the pipeline is not evenly supported (see Bedding Condition). Excessive bending stress can lead to circumferential cracking [3. The units of this parameter are *average daily traffic (ADT)* or *level*. This parameter is important for all pipe materials.

Location: A pipe in urban, suburban, rural or coastal area may be subject to different loads and conditions. A pipe serving a dense population area needs more capacity. A pipe in an industrial zone may be subject to highly acidic or alkaline conditions as well as other chemicals that may corrode the pipe. The unit of this parameter is *type (e.g., residential)*. This parameter is important for all pipe materials.

M

Manhole: Rigid connections frequently exist when the pipeline is connected to a structure such as a manhole. A manhole experiencing differential settlement can create high bending moments and shearing forces on the pipe [3. The units of this parameter are *condition level* and *type (e.g., material, type A)*. This parameter is important for all pipe materials.

Manufacture: The pipe material quality can vary based on the pipe manufacture. Errors due to manufacturing can result in a defective material that is more vulnerable to pipe failure. The unit of this parameter is *type*. This parameter is important for all pipe materials.

Material Type: The metallurgy of the pipe material type can dictate the resilience of strength and also the resistance to corrosion. Different pipe material types are designed for various service types and vary in design life, thickness, diameter, etc. The unit of this parameter is *type*.

Moisture Content: Soil moisture content indicates the amount of water present within the soil. The fact that moisture content can vary throughout the year should be taken into consideration. Prevailing moisture content can lead to soil corrosion [3. The unit of this parameter is *percent*. This parameter is important for metal pipes.

O

Odors: Odors in the system may be contributed by solid build-ups, poor system hydraulics and flat grade. The units of this parameter are *yes/no* and *level* (see H_2S). This parameter is important for all pipe materials.

Operational Pressure: Internal pressure is maintained at an effective level by the use of valves and pumps. The pressurized system results in a tensile stress (hoop stress) that acts on the pipe. This stress is a function of the operational pressure and the pipe diameter and wall thickness (see Diameter and Thickness). Excessive hoop stress can lead to longitudinal cracks in the pipe wall. The operational pressure causes a different type of stress on the pipe's bends and valves known as axial stress. Excessive pressure on these appurtenances can lead to circumferential cracking [3. This parameter is only applicable for force mains. The unit of this parameter is *psi*.

Overflow: Overflow may inundate surrounding soil and change loading on the pipe. Overflow occurs when the pipe is blocked or the system is overloaded, and results in backup flooding into building basement or street through inlets and manholes (see Backup Flooding). The units of this parameter are *yes/no* and *level*. This parameter is important for all pipe materials.

P

Precipitation: A large amount of precipitation can lead to possible flooding, an increase in the groundwater table, soil moisture content and soil erosion (see Flooding, Groundwater Table and Moisture Content). Extended external exposure of water to a pipeline can promote external corrosion, while the erosion of the soil can result in inadequate bedding conditions or landslides (see Bedding Condition). If there are cracks and holes in the pipe, a large amount of precipitation can lead to inflow/infiltration and exceeding capacity, and results in sewer overflow. The unit of this parameter is *inch/year*. This parameter is important for all pipe materials.

S

Seismic Activity: Seismic activity can result in increased pipe stresses and disturbances in the pipe-soil relationship, and cause failure. Pipe floatation may also occur due to liquefaction of the soil [3. The units of this parameter are *yes/no* and *level (e.g., frequent and magnitude)*. This parameter is important for all pipe materials.

Slope: The pipe slope affects the velocity of a gravity-flow sewer and may result in blockage, sediment and corrosion (see Velocity). Pipe slope may be derived from upstream invert elevation, downstream invert elevation and pipe length. The unit of this parameter is *gradient*. This parameter is important for all pipe materials.

Slope Stability: Soil stabilization is influenced by the slope of the ground. Earthquakes, reservoir draw-downs, heavy precipitation and floods can result in soil erosion or landslide potential, which can affect the pipe bedding condition and the alignment of the pipe (see Precipitation, Flooding and Bedding Condition). Anchor and/or thrust blocks may also be used to stabilize the pipe on a steep slope [3. The unit of this parameter is *yes/no*. This parameter is important for all pipe materials.

Soil Corrosivity: Soil corrosivity cannot be directly measured and is a function of several soil properties such as soil redox potential, soil pH, soil resistivity, soil sulfides, moisture content, etc. [4 (see Soil Redox Potential, Soil pH, Soil Resistivity, Soil Sulfides and Moisture Content). The corrosivity level of the soil can result in corrosion of the pipeline. The unit of this parameter is *level*. This parameter is important for metal and concrete pipes.

Soil pH: Soil pH is a measure of the soil acidity or alkalinity. A low pH represents an acidic soil promoting corrosion and is also a soil that serves well as an electrolyte. High alkaline conditions can also lead to corrosion of a ferrous material pipeline since it will be a soil that is high in dissolved salts, which yields a low soil resistivity [3. The unit of this parameter is *pH level* (see Soil Resistivity). This parameter is important for metal and concrete pipes.

Soil Redox Potential: Redox potential (also known as the reduction potential) is a measure of the tendency of the soil to attain electrons. Substances that accept electrons are capable of reducing or having a negative redox potential, which indicates an anaerobic condition. Soils that are anaerobic are regarded as potentially corrosive, predominately in ferrous material pipelines [3. The unit of this parameter is *mV*. This parameter is important for metal and concrete pipes.

Soil Resistivity: Soil resistivity is a measure of the soil to serve as an electrolyte and is often measured in the presence of ferrous material pipelines. The lower the resistivity value, the more likely the soil will serve as an electrolyte, which relates to an increase in soil corrosion activity. The soil temperature does have an impact on the soil resistivity; as the temperature decreases, the soil resistivity increases. Soil resistivity is also a function of the soil moisture content; the higher the moisture content, the lower the soil resistivity [4. The unit of this parameter is *Ohm-cm level* (see Moisture Content). This parameter is important for metal and concrete pipes.

Soil Sulfides: Soils containing sulfide indicate that there is a problem caused by sulfate-reducing bacteria. Soils with positive sulfide content are more prone to pipeline corrosion [3. The unit of this parameter is *percent*. This parameter is important for metal and concrete pipes.

Soil Type: The soil dead load and change in soil volume can be attributed to differing types of soil. The unit weight of the soil and depth of the pipe determine the total dead load resulting from the soil (see Cover Depth). This external load is usually accountable for ring deflection of the pipe. Soil types that are compressible can result in a greater pipe deflection, due to additional loading. Certain soil types are also more prone to expansion and contraction of soil, due to the wetting and drying cycles. In particular, the expansion of the soil can cause the external soil load to increase, which can result in axial and/or beam loads on the pipeline [3. The unit of this parameter is *type (e.g., clay, sand)*. This parameter is important for all pipe materials.

Stray Currents: Stray currents are caused by a local direct current (DC) flowing through the earth. These stray currents can be present if the pipe is near a transportation system such as a railway, or if other utilities are close to the pipe. Often these stray electrical currents can cause electrolytic corrosion in metal pipelines if they are not properly protected. Cathodic protection is the most common protection method of metal pipelines as a result of stray currents. The unit of this parameter is *yes/no* (see Cathodic Protection).

Surcharging: Surcharging in a gravity sewer in dry and wet weather should be monitored. Surcharge is described as a condition when the sewer flows full and under pressure. Surcharge occurs as a result of under design capacity or changing of system conditions such as deposit or blockage. Surcharging usually occurs during storms, due to high groundwater tables. Surcharging is usually measured in hydraulic head level (ft). The units of this parameter are *yes/no* and *ft.* This parameter is important for all pipe materials.

T

Tidal Influences: Tidal influences within coastal areas can influence the soil groundwater table. As the wave progresses inland, as a result of high tide, the groundwater table can fluctuate [4. The unit of this parameter is *yes/no* (see Groundwater Table). This parameter is important for all pipe materials.

Thrust Restraint: Unbalanced hydrostatic or hydrodynamic forces are known as thrust forces which can result in joint separation. These thrust forces are often controlled with the use of thrust blocks or restrained joints [4. This parameter is only applicable for force mains. The unit of this parameter is *yes/no.*

Trench Backfill: The trench backfill is responsible for providing sufficient surrounding support for pipe stability. Settlement of the backfill and/or pipe can create shearing or friction forces at the sides [3. The unit of this parameter is *type (e.g., Class A).* This parameter is important for all pipe materials.

Trench Depth: The trench depth should be dug accordingly for minimum cover to protect the pipe from possible loading and the frost line. The depth of the trench may be governed by existing utilities or other possible conditions [3. The unit of this parameter is *ft.* This parameter is important for all pipe materials.

Trench Width: The trench should be wide enough to provide adequate pipe support from the bedding and backfill (see Bedding Condition and Trench Backfill). Settlement of the soil or pipe can create shearing or friction forces at the side of the pipe [3. The unit of this parameter is *ft.* This parameter is important for all pipe materials.

Type of Cleaning: Some type of cleaning may damage the pipe. Typical cleaning methods used for wastewater pipe are water jetting, bucketing and chemical. The unit of this parameter is *type (e.g., jetting).* This parameter is important for all pipe materials.

V

Vintage: The pipe vintage can determine the metallurgy, uniformity, thickness, pressure class and available diameters of the various pipe materials (see Thickness, Pressure Limit and Diameter). For example, cast-iron pipe was initially pit cast; however, over the years, this casting method was changed to centrifugally spun cast. These variances due to pipe vintage can control the resiliency of the pipe material. The unit of this parameter is *year.* This parameter is important for all pipe materials.

W

Wall Thickness: The pipe wall thickness often governs the operational pressure of the pipe and is variable on pipe diameter and material type (see Operational Pressure, Diameter and Material Type). The magnitude of potential pipe stresses in relation to loading and depth of pipe can also be a function of the wall thickness (see Live Load and Cover Depth). Thickness is also a variable in analyzing the potential of corrosion and can dictate the amount of time corrosion pitting can be detrimental towards the pipe lifespan [4. The unit of this parameter is *inch.* This parameter is important for all pipe materials.

Wastewater Quality: Wastewater quality cannot be directly measured. It is a function of several properties such as wastewater pH, BOD, COD, temperature and chemical. The wastewater quality is thought to have an effect on the corrosion. This parameter is important for all pipe materials.

Wet/Dry Cycles: The wet/dry cycles as a result to climate can lead to expansion and/or contraction of the soil. The expansion of the soil can cause the external soil load to increase, which can result in axial and/or beam loads on the pipeline. Increased loading is also related to the shrinkage of the soil. The unit of this parameter is *yes/no* (see Soil Type). This parameter is important for all pipe materials.

Parameter Collection Protocol

Wastewater pipe infrastructure data has been previously recorded in municipality documents such as maps, maintenance records and daily field logs. In addition to the city

Table 1. A to L Parameter Sources

Parameter	Utility Records	Construction Specification	Hydraulic Model	Product Standards	Pipe Sample	Geotechnical Records	Aerial Photography	Customer Complaints	Other Testing	Online Database
Age	X	X								
Backup Flooding	X		X					X		
Bedding Condition	X	X							X	
Blockage	X		X					X	X	
Cathodic Protection	X	X								
Closeness to Trees	X						X			
Coating	X	X		X	X					
Condition	X									
Connection Density	X	X								
Cover Depth	X	X							X	
Design Life	X			X						
Diameter	X	X		X	X					
Dissimilar Materials/Metals	X	X								
Disturbances	X									
Exfiltration	X		X						X	
Extreme Temperatures	X								X	X
Failure Utilities	X									
FOG	X							X		
Flooding	X						X			X
Flow Velocity	X		X						X	
Frost Penetration	X								X	X
Function	X	X								
Groundwater Table	X					X			X	X
H_2S	X								X	
I&I	X		X						X	
Installation	X									
Joint Type	X	X		X						
Lateral	X	X								
Length	X	X								
Lining	X	X		X	X					
Load	X								X	

and utility documents mentioned above, staff interviews, survey questionnaires and informal meetings are always good sources for information. Often, compilation of this information is in paper format, which limits accessibility. Today, the most effective format for storage wastewater pipe infrastructure data would be an electronic overall base map such as Geographic Information System (GIS).

Wastewater pipeline data can be collected by direct or indirect methods; for example, direct methods such as various inspection methods, and indirect methods such as hydraulic modeling. For example, one of the most widely used inspection techniques for collecting internal wastewater pipeline information is called Closed-Circuit Television (CCTV). From CCTV images, the defects in the pipe such as cracks, fractures and holes are captured. Root intrusions through the cracked or broken pipe, Infiltration/ Inflow (I/I) and exfiltration can be detected via this technique as well. Other effective inspection techniques include smoke test, dye test and manhole inspection.

Data collection of pipe parameters can be time consuming and require expensive testing; therefore, selection of parameter collection techniques should be considered. To aid in the collection methods and protocols, a comprehensive list of parameter sources was compiled to give users the various collection techniques. Tables 1 and 2 illustrate each wastewater pipe parameter and list of possible collection sources.

Table 2. M to Z Parameter Sources

Parameter	Utility Records	Construction Specification	Hydraulic Model	Product Standards	Pipe Sample	Geotechnical Records	Aerial Photography	Customer Complaints	Other Testing	Online Database
Manhole	X	X								
Manufacture	X	X								
Material Type	X	X			X					
Moisture Content	X					X			X	
Odors	X							X	X	
Operational Pressure	X		X						X	
Overflow	X		X					X	X	
Precipitation	X									X
Seismic Activity	X									X
Slope	X	X					X			X
Soil Corrosivity	X					X			X	
Soil pH	X					X			X	
Soil Redox Potential	X					X			X	
Soil Resistivity	X					X			X	
Soil Sulfides	X					X			X	
Soil Type	X					X			X	X
Stray Currents	X	X				X			X	
Surcharging	X		X							
Tidal Influences	X					X	X		X	X
Thrust Restraint	X	X		X	X					
Trench Backfill	X	X							X	
Trench Depth	X	X							X	
Trench Width	X	X							X	
Type of Cleaning	X									
Vintage	X	X		X						
Wall Thickness	X			X	X					
Wastewater Quality	X								X	
Wet/Dry Cycles	X									X

Conclusion

An extensive study was conducted in order to provide a dependable list of pipe parameters taken from published studies, questionnaires and utility and pipe association interviews with the goal of creating a comprehensive list of all parameters which have an effect on wastewater pipe performance.

This paper summarized wastewater pipe performance parameters and their influences. A comprehensive list of wastewater pipe parameters presented in this paper aims at the broad understanding of the wastewater infrastructure system. Consideration of each pipeline parameter aids in determination of overall pipeline performance, as each factor has its own influencing role. Along with the prioritization of pipeline performance, financial costs as a result of compiling and collecting these parameters should also be taken into consideration in making asset management decisions. Additionally, collection of each parameter may be unreasonable due to cost and time constrains; therefore, a list of essential parameters should be given priority as the utility manager deems necessary.

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References

[1] Heastad, M., Walski, M. T., Barnard, E. T., Harold, E., Merritt, B. L., Walker, N., et al. (2004). Wastewater Collection System Modeling and Design, First Edition, Heastad Press, Waterbury CT.

[2] Najafi, M. (2005). Trenchless Technology-Pipeline and Utility Design, Construction, and Renewal, Water Environment Federation (WEF Press), ISBN 0-07 -142266-8.

[3] Computer Aided Rehabilitation of Sewer (CARE-S). (2002). European Commission – Fifth Framework Program. *Technical Report EVK1-CT-2002-00106*. Retrieved from http://care-s.unife.it.

[4] National Association of Sewer Service Companies NASSCO. (2003). Pipeline Assessment and Certification Program (PACP) Reference Manual. Pikeville, MD.

[5] Federation of Canadian Municipalities and National Research Council (NRC). (2004). Assessment and Evaluation of Storm and Wastewater Collection Systems, A Best Practice by the National Guide to Sustainable Municipal Infrastructure. ISBN 1–897094–72–8, Canada.

[6] Stone, S., et al. (n.d.). Decision-Support Tools for Predicting the Performance of Water Distribution and Wastewater Collection Systems, EPA/600/R-02/029, National Risk Management Research Laboratory Office of Research and Development U.S. Environmental Protection Agency (USEPA), Cincinnati, OH.

[7] Garcia, C., Abraham, M. D. Gokhale, S., & Iseley, T. (2002). Rehabilitation Alternatives for Concrete and Brick Sewers. ASCE Practice Periodical on Structural Design and Construction.

[8] Kellagher, R., et al. (2002). Development of Guideline for the structural Hydraulic and Environmental Rehabilitation of Sewer, SMT4 – CT98 – 2272. Retrieved from http://www.hydroinformatics.org/SRguide/home.html.

[9] Le Gouellec, Y. A., & Cornwell, D. (2007). Installation, Condition Assessment, and Reliability of Service Lines. American Water Works Association (AWWA) Research Foundation.

[10] Makar, J. M., Desnoyers, R., & McDonald, S. E. (2000). Failure Modes and Mechanisms in Gray Cast Iron Pipe, NRC-CNRC. Presented at Underground Infrastructure Research 2001. Waterloo, Ontario.

[11] Rajani, et al. (2000). Investigation of Grey Cast Iron Water Mains to Develop a Methodology for Estimating Service Life, American Water Works Association (AWWA) Research Foundation.

[12] Starling, N. et al. (2007). Characterization of Lead Pipes Used in the Water Industry: Extrusion Pro-

cessing, Alloy Microstructure and Their Role in Service Failures. *Materials Science and Technology, 23* (5), 600-605.

[13] Szeliga, M. J., & Simpson, D. M. (2003). Evaluating Ductile Iron Pipe Corrosion, Pipelines.

[14] UK Water Industry Research (UKWIR). (2002). Nationally Agreed Failure Data and Analysis Methodology for Water Mains: Volume II, Protocol for the Capture and Reporting of Data on Mains Failures, UK.

[15] Al-Barqawi, H., & Zayed, T. (2006). Condition Rating Model for Underground Infrastructure Sustainable Water Mains, *ASCE Journal of Performance of Constructed Facilities*, *20*(2), 126-135.

[16] CARE-W. (2002). Construction of a Control Panel of Performance Indicators for Rehabilitation, Report #2 Validation of the Rehabilitation Performance Indicators System, Lisbon, pp. 1-95.

[17] Chughtai, F., & Zayed, T. (2007). Structural Condition Models for Sewer Pipeline, Pipelines. *ASCE Conference Proceedings*.

[18] Deb, A. K., Grablutz, F. M., Hasit, Y. J., Snyder, J. K., Loganathan, G.V., & Agbenowski, N. (2002). Prioritizing Water Main Replacement and Rehabilitation, AWWARF. Denver, CO.

[19] Elsayegh, H. K., Hutchinson, R. E., & Norris, L. (2007). Clean Water Atlanta: A Comprehensive approach to QA/QC from SSES to Rehabilitation Design. Water Environmental Federation.

[20] United States Environmental Protection Agency (USEPA). (1999). Collection Systems O&M Fact Sheet Sewer Cleaning and Inspection, EPA 832-F-99 -031, Office of Water Washington, D.C.

[21] Kathula, V. (2001). Structural Distress Condition Modeling for Sanitary Sewer, Ph.D. Thesis, Civil Engineering, Louisiana Technological University.

[22] Mays, L. W. (2002). *Urban Water Supply Handbook.* Mc-Graw Hill Companies Inc, NY.

[23] Mehta, C. R. (2006). Identification and Characterization of Parameters for Sewer Pipe Condition Rating. MS Thesis, Pennsylvania State University, PA.

[24] Nelson, R. E., Hsiung, P. H., & Witt, A. A. (1999). Optimization of Collection System Maintenance Frequencies and System Performance. American Society of Civil Engineers, Washington, D.C., 146.

[25] Royer, M. D. (2005). White Paper on Improvement of Structural Integrity Monitoring for Drinking Water Mains. EPA/600/R-05/038.

[26] Schrock, B. J. (1991). Pipeline Systems Rehabilitation Workshop. San Jose, CA.

[27] Makar, J. M. (2000). A Preliminary Analysis of Failures in Grey Cast Iron Water Pipes. *Engineering Failure Analysis*, *7*, 43-53.

[28] Rajani, B. B., Zhan, C., & Kuraoka, S. (1996). Pipe-Soil Interaction Analysis of Jointed Water Mains. *Canadian Geotechnical Journal, 33*(3), 3-11.

[29] Boot, J. C. (1998). Elastic Buckling of Cylindrical Pipe Linings With Small Imperfections Subject to External Pressure. *Journal of Intl. Society of Trenchless Technology*, *12*(2).

[30] Heger, F. J., Liepins, A. A., & Selig, E. J. (1985). SPIDA: An Analysis and Design for Buried Concrete Pipe. *Proceedings of the Intl. Conference of Pipelines*, ASCE, (pp.143-154).

[31] Davies, J. P., Whiter, J. J., Clark, B. A., Ockleston, G. O., & Cunningham, R. J. (1999). Application of Interaction Matrices to the Problem of Sewer Collapse. *Proceedings of 11th European Sewage and Response Symposium*, Munich.

[32] Serpente, R. F. (1993). Understanding the Models of Failure for Sewers, *Proceedings of Intl. Conference of Pipeline Division*. ASCE, New York.

[33] Smith, L. A., Fields, K. A., Chen, A. S. C., & Tafuri, A. N. (2000). Options for Leak and Break Detection and Repair of Drinking Water Systems. Columbus, OH: Battelle Press.

[34] Association, A.W.W. (2004). Steel Pipe-A Guide for Design and Installation. (4th ed.). A.W.W. Association. Denver, CO: American Water Works Association.

[35] Moser, A. P. (2001). Buried Pipe Design. (2nd ed.). New York, NY: Mc-Graw Hill Companies.

[36] Buried Flexible Steel Pipe Design and Structural Analysis. (2009). ASCE Manuals and Reports on Engineering Practice No. 119. Reston, VA: American Society of Civil Engineers.

[37] Moser, A. P. (1990). *Buried Pipe Design*. New York, NY: McGraw-Hill.

[38] Association, A.W.W. (2005). Polyethylene Encasement for Ductile-Iron Pipe Systems. American Water Works Association: Denver, CO.

[39] Ling, H., Mohri, Y., Kawabata, T., Liu, H., Burke, C., & Sun, L. (2003). Centrifugal Modeling of Seismic Behavior of Large-Diameter Pipe in Liquefiable Soil. *Journal of Geotechnical and Geoenvironmental Engineering, 129*(12), 1092-1101.

[40] Kleiner, Y., Rajani, B., & Krys, D. (2010). Impact of Soil Properties on Pipe Corrosion: Re-Examination of Traditional Conventions. in Water Distribution System Analysis. Tucson, AZ.

[41] Smith, T. E. (1994). Analysis of Tidal Fluctuation Effects on a Confined and Unconfined Aquifer, in FOCUS Conference on Eastern Regional Ground Water Issues. Newburyport, MA. p. 757-771.

[42] Stathis, J. A. (1998). A Model for Determining Leakage in Water Distribution Systems, in Civil Engineer-

ing. Virginia Polytechnic and State University: Blacksburg.

[43] Thrust Restraint Design for Ductile Iron Pipe. (2006). Ducile Iron Pipe Research Association, DIPRA.

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ELECTRICAL ENGINEERING TECHNOLOGY UNDERGRADUATE RESEARCH EXPERIENCE: PHASE TORQUE™ —A DESIGN FOR REAL-TIME MONITORING OF TORQUE APPLIED TO A ROTATING SHAFT

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Carl Seidel, Michigan Technological University

Abstract

As part of the continuous effort in developing industry partnerships that will lead to priority consideration of graduates from The School of Technology, an industrial partner collaborated with The Electrical Engineering Technology (EET) Program at Michigan Technological University to engage an EET student in researching Engineering problems. This undergraduate research experience is offered through an independent-study course and is used to fulfill the degree program requirements. This research project is a continuation of work originally conducted by the industrial partner. The project makes use of high-speed, field-programmable-gate-array-based data acquisition to monitor the relative positions of two cogged wheels spaced out on a rotating shaft that is powered on one end and loaded on the other. Once the twist in the shaft is measured, the applied torque can be calculated mathematically allowing for real-time monitoring of loads with minimally invasive setup. The goal was to take the initial research by the industrial partner and advance it as far as possible within the limited time frame of a single fourteen-week semester, while focusing on areas relevant to an Electrical Engineering Technology degree such as signal acquisition, data processing and Field Programmable Gate Array (FPGA) hardware design.

This paper details the undergraduate research experience, an independent-study project, for the Electrical Engineering Technology program at Michigan Technological University conducted with the industrial partner. The project consisted of further development of a data-acquisition system that can monitor the amount of torque applied to a rotating shaft in real time. The design focuses on software and FPGA hardware development for real-time data acquisition and processing.

Introduction

Usually, academic institutions teach students in a traditional environment composed of traditional lectures and laboratories—the lack of engaging students in solving real-world engineering problems reflects negatively on students' ability to compete in a global market. A strong link between academia and industry must be established. This partnership is a two-way street with advantages for both parties [1]. Today's students need both perspectives if they are going to be able to compete in the highly competitive global economy. They need to be more job-ready and know more than just theories [2]. Industry demands for ready-to-contribute graduates continue to rise; they are looking for graduates who can contribute on day one rather than a graduate who will need further training. To respond to industry's needs, academia and industry have been exploring possibilities of working together, either informally or formally, including student internships, faculty exchanges and industry-sponsored capstone projects. Collaboration between academia and industry is a two-way street, where both parties enjoy many advantages of this collaboration. Academia will benefit from this collaboration by providing students with marketable skills, securing additional funding for possible research and accessing state-of-the-art technology. On the other hand, industrial organizations will benefit from this collaboration by having access to academia's talent provided by both faculty and students at a reduced rate, and access to a common pool of talented students for a possible hire. The goals are always to bridge the gap between academic programs and industry demands, the needs and challenges of the industry had to be transformed to the classroom to make sure that the graduates compete in a challenging marketplace.

Industrial collaboration can be represented in many different forms. One form of industrial collaboration can be done by utilizing an effective Industrial Advisory Board (IAB). The IAB usually helps to keep the program current and relevant to industry needs; help from the IAB can be used in assessing academic programs' student outcomes to meet accreditation requirements [3]. Second, industrial collaborations can be established through a possible internship program, where industry partners hire students for their company as interns on a try-before-you-buy basis [2], [4]. The third possible collaboration is through sponsoring possible capstone projects or undergraduate research experiences, where students work on a real-world engineering problem, which eventually will result in a full-time employment opportunity for the students. Earlier research [5], [6] showed the importance of industrial involvement in the capstone environment, which became more than just the financial support. However, support in the form of equipment, materials and technical consulting is common and, in most cases, necessary [6-8]. Other forms of industrial support include providing awards for meritorious designs and assisting in the evaluation of teams and projects [9].

Each of these forms has the elements of bringing real-world problem-solving skills to the student and at the same time helping the industrial partner. Many academic institutions manage to establish a strong collaboration with local and regional industrial partners; Morehead State University represents an example of how a strong relationship with local industrial partners helped the department of Industrial and Engineering Technology program survived and to become one of the most successful departments at the university [10].

The undergraduate research Experience is a reflection of quality education. Academic institutions aim to integrate research experiences in their curricula by establishing a partnership with both local and regional industry [11]. The Electrical Engineering Technology program at Michigan Technological University established a relationship with possible industrial partners to provide students the opportunity to work on real-world engineering design problems with possible industry supervisors in which the student establishes a working relationship with an industrial supervisor who works with them to develop a project and to prepare a work plan. The industry supervisor evaluates the student's performance and work closely with the student's academic advisor on monitoring the progress the student makes towards achieving the project's goals.

This project was conducted with the industrial partner as an Electrical Engineering Technology undergraduate independent-study course for the spring, 2012, semester under the direction of a faculty member at Michigan Technological University. The project consisted of a continuation of work originally conducted by the industrial partner. Specifically, the project made use of high-speed FPGA-based data acquisition to monitor the relative positions of two cogged wheels spaced out on a rotating shaft that was powered on one end and loaded on the other. Once the twist in the shaft is measured, the applied torque can be calculated mathematically allowing for real-time monitoring of loads with minimally invasive setup. The goal was to build upon the initial research done by the industrial partner, progressing it as far as possible within the limited time frame of a single fourteen-week semester, while focusing on areas relevant to an Electrical Engineering Technology degree such as signal acquisition and conditioning, data processing and FPGA hardware design.

Electrical Engineering Technology Program

The EET program offers a Bachelor of Science in Electrical Engineering Technology and is designed to train the future workforce directly in response to industry needs. The EET program is application-oriented and focuses on preparing graduates for entry into the workforce upon graduation. Graduates of the program are electrical engineering technologists with career options in micro-controller applications, robotics, industrial automation, instrumentation and control.

A major strength of the EET program in attracting and retaining interested students is the emphasis on applied laboratory experience. The program has a solid record of career placement among employers seeking graduates that are productive upon entering the workforce. The university as a whole has maintained a placement rate of over 95% in recent years, in spite of the difficult economic times. All School of Technology faculty members have a minimum of three years of industrial experience, which enhances the ability of the School to access industry support and place engineering technology graduates. The faculty members have a strong commitment to the integration of practical laboratory experience with engineering technology fundamentals.

Electrical Engineering Technology Undergraduate Research Experience

Course Objectives

The course places an emphasis on the importance of integrating undergraduate experience in the Electrical Engineering Technology curriculum through partnership with local and regional industry. This research experience consists of part-time employment (8-10 hrs/week) at Industrial Partner campus that specializes in engineering wireless telemetry systems. A large portion of the work was focused on the engineering and design of the electrical components used for sensing, transmitting and receiving data as well as powering the devices. Upon successful completion of this course, students will be able to:

- Prepare background research on applied electrical engineering technology;

- Organize research and data for synthesis;
- Prepare written reports;
- Prepare and present oral reports;
- Coordinate and work to meet scheduled deadlines and facilities, manage resources, etc.; and,
- Consider non-engineering considerations in your work (e.g., economic issues, marketing issues, esthetics).

Course Structure

The undergraduate research experience course is three credit hours. Students will meet with their instructors weekly to discuss progress to date. The entire grade is based on the satisfactory completion of the project and the presentation of the final results in an appropriate engineering report at the end of the semester. The final grade is based on student performance throughout the semester. The timeline for submitting these materials will be as follows:

1. Final Report (due 2 weeks before final exams start)
2. Poster (due 1 week before final exams start)
3. Prototype (due 3 weeks before final exams)
4. Final and midterm presentations
5. Project proposal and portfolio (by the end of the 3rd week)
6. Bi-weekly progress report

Engineering Design System Description

The following sections cover the specific design choices and theory behind each major sub-section of this design. Concepts that will be covered include both hardware and software design components of the FPGA real-time data acquisition and processing system.

System Overview

The project design requirement was to outfit a piston pin from a diesel engine with an array of seven thermocouples to monitor piston pin temperature and an optical transducer to observe the relative rotation of the piston pin. Figure 1 is an image of the telemetry setup that shows the cogged wheel on the end piston pin and the optical transducer mounted on the piston that is used to monitor pin rotation during engine operation.

The purpose of the Phase Torque™ system is to monitor the torque applied to a rotating shaft. This has many potential applications including monitoring of industrial equipment, or use in research and design of automotive drivetrain systems. The Phase Torque™ system has many benefits over conventional torque monitoring systems that are currently in place. The system is designed to be as unobtrusive as possible, leading to simpler installations and greater ease-of-use.

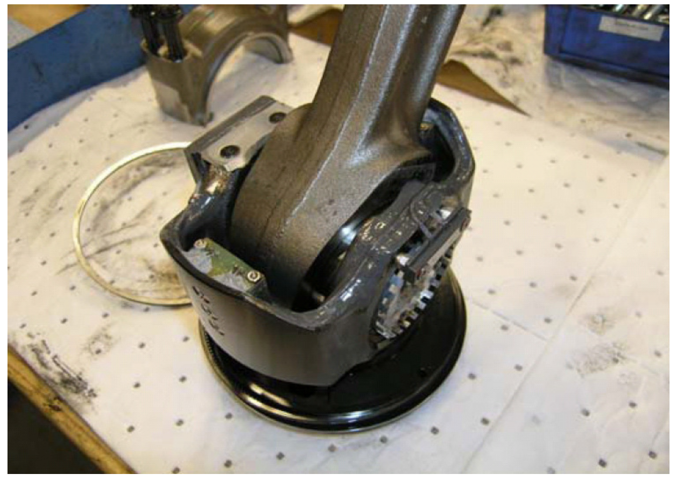

Figure 1. Piston and Rod Combination Outfitted with Pin Temperature and Rotation Sensors [12]

The concept of the new design is based on the idea that it would be possible to monitor the amount of torsion in a rotating shaft and, therefore, the applied torque, using two cogged wheels whose position relative to each other would change due to the twisting of the shaft as the applied torque changed [12].

Figure 2 is a block diagram of the Phase Torque™ system. For the initial tests, an electric motor was used to turn a shaft connected to an alternator. The alternator had a load that could be varied from 0 to 900 watts. Three cogged wheels were attached on the shaft, two with 36 teeth and one with only one tooth. The wheel with one tooth was used as a reference pulse to synchronize data readings. The two wheels with 36 teeth were used to measure the rotational displacement along the shaft due to the load torque. Optical interrupters were used to sense the passing of the teeth and to trigger the FPGA-based data-acquisition hardware. The data from the data-acquisition hardware were sent to a computer where they were analyzed.

FPGA-Based Data-Acquisition Circuit Design

The data-acquisition system was an FPGA-based device with six digital and six analog inputs that operates at a high frequency. The design also requires applying data-processing routines written in Visual Basic (VB) for post-processing the data and implementing them on the FPGA for real-time data processing. The goal was to produce a self-contained unit that can acquire, process and output all of the relevant data needed for monitoring shaft torque.

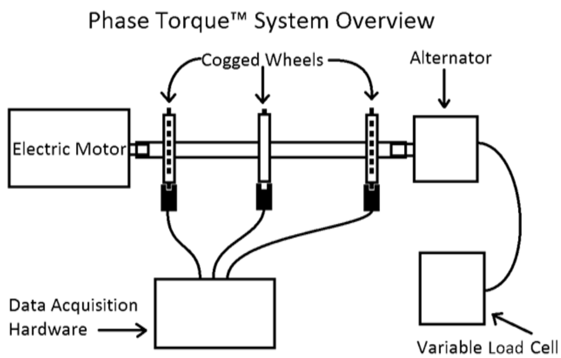

Figure 2. Block Diagram of the Phase Torque™ System

Hardware Circuit Description

Figure 3 is a block diagram of the FPGA data-acquisition and processing system. There are four input signals, the signals from each of the optical interrupters and a push-button signal used for calibrating the system. The time between successive pulses from wheel0 and wheel1 will be used to calculate the angle of twist in the shaft. This value will be corrected by reading that tooth's calibration value from a calibration register. A counter will keep track of the current tooth number and will use the wheel with only one tooth, shown as wheel2 in the block diagram, as a reference. After the correction factor is applied to the angle value, this will then pass through the averaging filter, which will then pass this data on to the USB interface controls so that the data can be sent via USB or other communication interface technology. There are seven major components in the FPGA design, the rising edge detector, the tooth number counter, the RPM counters, the tooth event timer, the calibration register memory interface, the correction factor application block and the averaging filter block.

Rising Edge Detector: The rising edge detector is fairly straightforward and similar to many examples of rising edge detectors seen elsewhere and implemented in VHDL. It ensures that the system always triggers off of the rising edge of a signal so that the timing is as accurate as possible.

Tooth Number Counter: The tooth number counter consists of two 8-bit counters that increment with the tooth pulses of each wheel. The block diagram for the tooth number counter can be seen in Figure 4. The counters are reset by a high signal on the wheel2 input, which is the reference pulse. This signal is also used as the clock input to the output registers, which hold the values for the number of teeth on each wheel. The value of the current tooth is also output from this block for use by various other components in the design. Due to the register size of the counter (eight bits), wheels with up to 256 teeth can be used.

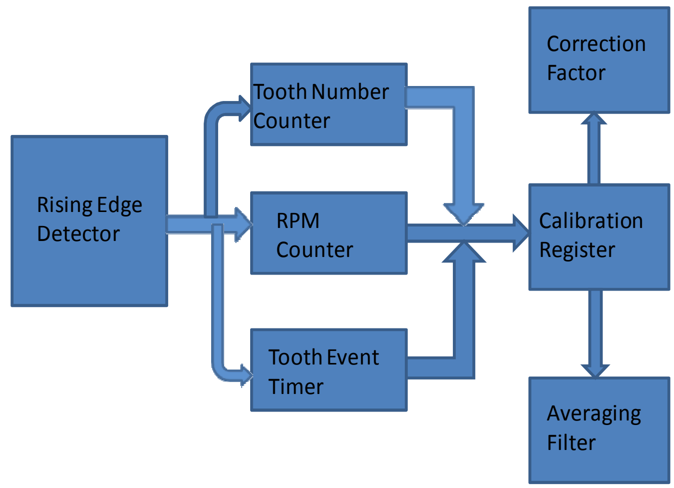

Figure 3. Circuit Block Diagram

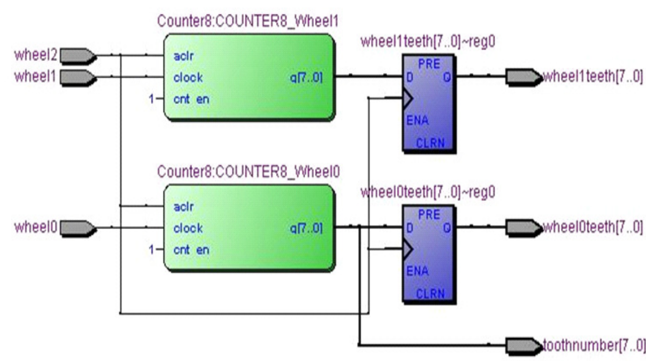

Figure 4. Tooth Number Counter Block Diagram

RPM Counter: The RPM counter is a simple, 32-bit interval counter that records the amount of time between pulses on the single-toothed wheel. Acquiring the RPM signal is important because it allows for the horsepower of the system being monitored to be calculated by using the measured torque.

Tooth Event Timer: The tooth event timer is what tracks the amount of time that has passed between successive teeth on the two wheels. It uses a 32-bit counter to keep track of the number of clock ticks between inputs. The counter starts in the middle of its 32-bit range and, depending on which tooth crosses first, it either counts up or down. This allows for negative values to be handled by the hardware as well.

Calibration Register: The calibration register memory interface utilizes the 8 kb of User Flash Memory (UFM) available on the Altera MAX II FPGA used in the design. However, the UFM utilizes 16-bit registers, and the timer used in the tooth event timer uses 32-bit values. In order to store these 32-bit values into the 16-bit registers of the UFM, each 32-bit value is first separated into two 16-bit values, one corresponding to the first 16 bits and the other corresponding to the second 16 bits. So for each read/write operation from the UFM to read/write a calibration value, two reads or two writes need to take place. A state machine was created which first reads/writes the low bits then reads/writes the high bits. In the case of a read operation, the high and low bits are then concatenated to create the desired 32-bit output. The 8 kb size of the UFM allows storage of 256 32-bit values, which is just the right size for storing calibration data for the maximum number of teeth dictated by the 8-bit counters used in the tooth-number counter block.

Correction Factor Circuit: The correction-factor application block is used to apply the appropriate correction factor to the value from the tooth event timer. When the calibration data for the current tooth is successfully read from the UFM, the correction-factor application block subtracts this calibration value from the output of the tooth event timer. The output from this goes to the averaging filter block.

Averaging Filter: The averaging filter block is where the averaging routine, developed first in software, is implemented. The averaging filter consists of a state machine that steps through the averaging process.

As it currently stands, the output from this circuit is an average value given in a number of clock cycles. Additional logic blocks will need to be added to convert this time-based value into a torque value. The design was coded using VHDL and compiled with Altera's Quartus II software [13]. Also, all current testing of the design was done solely with simulations. In order to implement the FPGA design in hardware, the USB interface and controls will need to be implemented within the design to be able to send the data to a computer for storage and analysis.

Software Design

The software was written in Microsoft Visual Basic to provide an easy environment to analyze and record the data and visually compare the results. The two main parts of the software written for this project focused on calibrating the system and processing the data recorded by the data-acquisition system, specifically the averaging algorithm.

Due to the need for high resolution for measuring angle variations, the system had to be calibrated to eliminate as many variables as possible. The calibration processes used effectively eliminate any erroneous readings due to machine tolerance variations in the width of the teeth. This was done by running the setup with no load applied to the shaft and taking the average angle value read for corresponding teeth between the two wheels with 36 teeth. The wheel with one tooth was used to maintain synchronism in the data, to ensure that the corresponding teeth between each wheel were counted correctly. After calibration was complete, the amount of noise in the data was greatly reduced. Without this calibration, the noise present would be greater than any desired reading you would want to get and, therefore, the system would not work. The raw data from this run varied by about 0.45°. After the calibration was applied, the data variation was reduced to about 0.16°. Figure 5 shows the impact of the calibration process on data captured for 30 seconds and compares the raw data with the calibrated data. Initially, the raw data varied from approximately 5.85° to 6.3°. With the calibration process applied, the data changed to vary from 0.1° to -0.05°. The blue trace in the graph represents the raw data with the left vertical scale. The red trace represents the calibrated data with the right vertical scale.

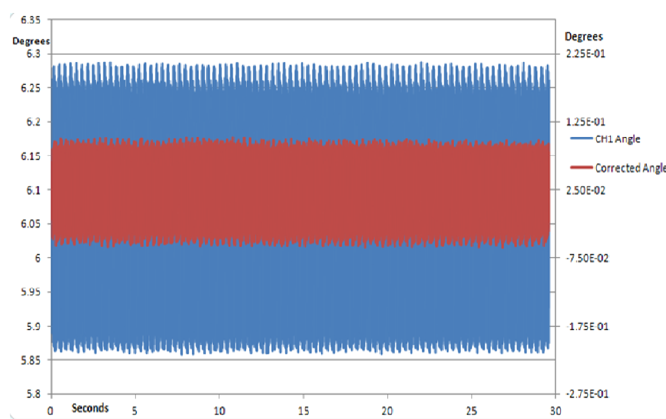

Figure 5. Overlay of Raw and Corrected Data

To decrease the noise in the data even further, an averaging filter was used. The averaging filter uses a running weighted average. This is better than a traditional average because as each new piece of data is acquired, it can be combined with the current average and the average value can be updated immediately, rather than accumulating a set number of data points then dividing the sum by the number of data points, and updating the average. The depth of the averaging filter was used to add weighting to the data so that more recent data had a greater effect on the average than old data. This filter depth is selectable and effectively alters the smoothing of the data. A higher filter depth puts more weighting on older data so the average value is slower to react to changes in the raw data, which smoothes out the average value. A compromise between smoothness and reaction time must be reached in order to provide a stable reading that accurately reflects the current state of the device being measured. Figure 6 shows the average value. It can be seen that the range in values is now much lower. The initial ramp up is due to the averaging function and the weighting values used.

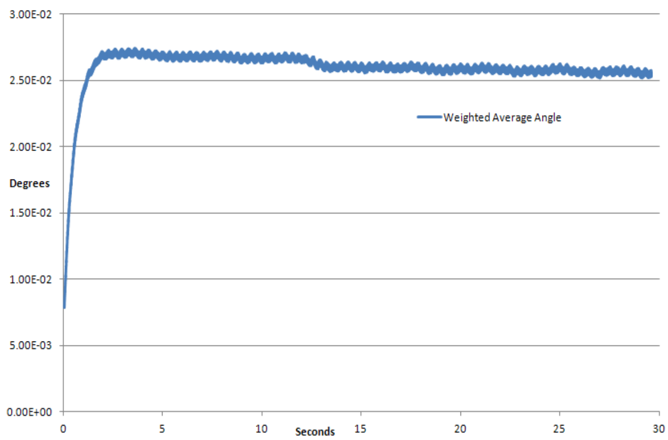

Figure 6. Weighted Average Angle Separation Data

In addition to measuring the angle between corresponding teeth on the two wheels, the software can also count the number of revolutions, identify each individual tooth for each wheel and monitor the rotational speed of the shaft. The rotational speed of the shaft allows for a real-time power reading in addition to the real-time torque reading.

System Verification

The mechanical layout of the test bed essentially follows the system block diagram. The electric motor spins the shaft that turns the alternator. The shaft has the three-cogged wheels on it and the alternator is loaded down with a variable load. The load-bank consisted of nine 100-watt, 12-volt light bulbs. It also had an aluminum heat sink and a large fan to keep it cool. Each of the cogged wheels had one optical interrupter switch mounted below it. The signals from the optical interrupter switches were fed to the FPGA-based data-acquisition system, which was connected to the computer. The end of the shaft that the alternator threads into was mounted on a pillow-block bearing. This was done so that the alternator could be free-floating. With the alternator free to rotate, an analog load cell was mounted to the alternator. The data from this analog load cell was fed to one of the analog input ports of the data-acquisition system and was then used to verify the torque readings obtained from the optical interrupter switches. The load cell reading was used purely for testing, comparison and validation of results during the development of this project.

The limitations that were encountered during the development of the system were simply due to the setup being used. One of the problems identified through the use of the current setup was the lack of alignment between the motor, the pillow-block bearing and the alternator. This caused the shaft to bind and bend ever so slightly each time it turned over, which added to the noise and vibrations seen in the data. The motor used was simply spot-welded to a stamped steel bracket bolted to the base of the test bed. Even if the motor were perfectly aligned with the pillow-block bearing while resting, under load this stamped-steel bracket would bend and twist causing the motor to move out of alignment, resulting in the same vibrations and unwanted bending forces on the shaft.

Conclusion

The Undergraduate Research Experience is directly related to and a reflection of quality education. Academic institutions aim to integrate research experience in their curricula by establishing a strong partnership with both local and regional industry. The Electrical Engineering Technology program at Michigan Technological University established a relationship with industrial partners to provide students with the opportunity to work on real-world engineering design problems. This project was conducted with the industrial partner as an Electrical Engineering Technology undergraduate independent study course for the spring, 2012, semester under the direction of a faculty member at Michigan Technological University.

The project consisted of the development of a data-acquisition system that can monitor the amount of torque applied to a rotating shaft in real time. The design was focused on software and Field Programmable Gate Array hardware development for real-time data acquisition and processing. This Electrical Engineering Technology Undergraduate Research opportunity will advance undergraduate research within the School of Technology, fostering enhanced real-world engineering design projects and enhancing the students' classroom experience using undergraduate research. Such an approach to the education of engineering technology students meets the expectations of ABET accreditation standards [14] by connecting students to the solution of real problems.

References

[1] Alaraje, N., Sergeyev, A., Kennedy, W., & Seidel, C. (2012). Professional Development Opportunity for Electrical Engineering Technology Educators in VHDL and FPGA Design. *The Technology Interface International Journal*, *12*(2).

[2] Richter, D., & Loendorf, W. (2007). Faculty with Industrial Experience Bring a Real World Perspective to Engineering Education. *ASEE Annual Conference & Exposition*.

[3] Seybert, T. A. (2010). Using an Industrial Advisory Council for Student Outcomes Assessment: A Work in Progress. *The Technology Interface International Journal*, *11*(1).

[4] Craig, W. O. III. (2010) Preparing the Engineering Technology Graduate for the Global Marketplace. *The Technology Interface International Journal*, *10* (3).

[5] Todd, R. H., Magleby, S. P., Sorensen, C. D., Swan, B. R., & Anthony, D. K. (1995). A Survey of Capstone Engineering Courses in North America. *Journal of Engineering Education 84*(2), 165-174.

[6] Banios, E. W. (1992). Teaching Engineering Practice. *Proceedings Frontiers in Education Conference, IEEE*. (pp. 161-168).

[7] Rochefort, S., (1985). An Innovative ChE Process Laboratory. *Chemical Engineering Education*, *19*(3), 150-155.

[8] Born, R. C., (1992). A Capstone Design Experience for Electrical Engineers. *IEEE Transactions in Education*, *35*, 240-242.

[9] Thorpe, J. F. (1984). Design of Mechanical Systems: A Capstone Course in Mechanical Engineering Design. *ASEE Annual Conference & Exposition*.

[10] Mohammed, J. & Mason, S. (2008). Departmental Survival through Collaborative Industrial Partnership. *ASEE Annual Conference & Exposition*.

[11] Brown, H., & Cheney, A. (2004). Enhancing the Undergraduate Experience for Advanced Education and Research Careers. *ASEE Annual Conference & Exposition*.

[12] Clark, K., Antonevich, J., Kemppainen, D., & Barna, G., (2009). Piston Pin Dynamics and Temperature in a C.I. Engine, *SAE Int. J. Engines 2*(1), 91-105

[13] Altera University Program. (n.d.). Retrieved February 19, 2013, from http://www.altera.com.

[14] ABET. (n.d.). Retrieved February 19, 2013, from http://www.abet.org.

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AUTHENTIC TEACHING AND LEARNING THROUGH EXTRA-CURRICULAR ACTIVITIES

Mehmet Emre Bahadir, Murray State University; Joseph Rudy Ottway, Murray State University

Abstract

The role and effect of student organizations on the academic and professional development of students has been a subject of research by many educators. It has been proven that there is a positive relationship between the academic performance of students and their extracurricular involvement through student organizations [1]. This study emphasized the value of student organizations from an "authentic teaching and learning" perspective by exemplifying the "Toy Production" activities of an Engineering Graphics and Design student organization at a four-year undergraduate technology program. The activities are explained step-by-step from developing the design idea to selling the finished product. A detailed analysis of the toy production process identified the potential benefits of the activities for the students. Integration of retention, advising and recruitment functions into the club activities is described as well. At the conclusion of the paper, the results of two surveys are provided to present the students' attitudes towards the student organization. Students' perceptions of acquired professional and academic skills demonstrate the value of the club activities.

Introduction

At institutions of higher education, the responsibilities of faculty encompass three areas: teaching, research and service. Although expectations and workloads for each area differ depending on the type of the institution, teaching is always considered to be the central mission of faculty at comprehensive universities [2]. Most of the time, roles and responsibilities of educators in those areas overlap conceptually and practically. With the limited time and resources available, it is desirable to integrate different roles and responsibilities in one task. As presented in this study, embedding authentic teaching activities into service-oriented tasks would fulfill both teaching and service responsibilities. This study focused on developing an extracurricular activity by adopting authentic teaching methods and incorporating service tasks for retention, advising and recruitment purposes.

Teaching has been changing and evolving continuously with the introduction of new methods, tools and settings [3], [4]. New strategies such as experiments, field work, discussions, tests, papers and projects are transforming education from a passive, unidirectional activity to an interactive, empowered and learner-oriented process [5-7]. Rather than just transferring the knowledge, more emphasis is laid on teaching how to effectively use those skills and knowledge in real life through authentic teaching tasks [8]. Engineering and technology students, who are described as "do-ers", would benefit more from kinesthetic-based learning with more hands-on and problem-based teaching strategies [9]. In this regard, technical fields require different approaches than liberal arts or natural sciences. The common problem is the lack of enough authentic problem-solving and project-based activities in the curricula [8].

At most institutions, service is considered to be of less importance [2], but there are times that retention, advising and recruitment efforts become more critical for academic programs. Currently, unpredictability of the world's economy, decline of the population of 18-year-olds, federal- and state-level financial-aid cuts and college tuition increases have negatively impacted enrollment in higher education in the U.S. [10-12]. Retention and recruitment efforts are more crucial for technology programs because of the public's negative views of production- and manufacturing-related careers [13]. For most people in the U.S., manufacturing is still considered to be dirty, unsafe and uninteresting [14]. Another factor contributing to the enrollment drop in technical fields is the future trend in manufacturing jobs. Since 1975, global outsourcing and high worker productivity ratings have created a steady decline in the number of manufacturing jobs in the United States [15], [16]. The Employment Projections report for 2020 indicates that the decline will continue for design, drafting and manufacturing occupations until the year 2020 [17]. As a result, high school students and their parents have a negative view of careers in manufacturing [13]. According to a 2012 survey, only 17% of high school students are encouraged by their parents to pursue a career in manufacturing and 80% believe that manufacturing jobs are the first to be outsourced or moved to other countries [18]. In these circumstances, retaining, recruiting and educating the next generations of skilled workers for industry has become more challenging.

Literature Review

At higher education institutions of engineering and technology, many types of student organizations operate with different functions and purposes. Among all student organizations, four types get the most interest [19]: student chapters of professional organizations (e.g., the Association of Technology, Management, and Applied Engineering; the American Society for Engineering Education; and, the Society of Manufacturing Engineers), honor societies of engineering and technology majors (e.g., the International Honor Society for Technology; and, the Engineering Technology National Honor Society), diversity organizations (e.g., the National Society of Black Engineers; the Society of Women Engineers; and, the Society of Hispanic Professional Engineers) and project-oriented organizations. These student organizations or teams focus on design/build projects to participate in collegiate competitions such as the American Solar Challenge, Baja SAE and Solar Splash. These projects provide ideal conditions for practical applications of technical skills, time management, interpersonal skills and leadership [20-22].

Certainly, not all projects or activities of student organizations can be regarded as authentic learning activities. Moreover, the real challenge is transforming the authentic tasks and their context into a learning tool. The most significant characteristic of authentic learning can be described as an enhanced educational setting with increased motivation and enthusiasm. [23]. Studies prove that authentic learning can be successfully adopted for any level of education, from K-12 to graduate education [24], [25]. Four elements mentioned in the literature to be the most crucial traits of any authentic learning task are: 1) real-world problems that engage learners in the work of professionals; 2) inquiry activities that practice thinking skills and metacognition; 3) discourse among a community of learners; and, 4) student empowerment through choice. In this regard, previously mentioned competition projects possess potential value as Authentic Learning activities [26].

Considerable research has been conducted and many theories have been developed around extracurricular activities and their effects on student development. It is necessary to state that there is a positive relationship between academic performance and extracurricular involvement [27]. This is significant because extracurricular involvement is generally considered as a distraction that diverts students from academic studies [28]. Cognitive and communicative skills are found to be associated with both academic and extracurricular involvement, but self-confidence and interpersonal skills are primarily associated with extracurricular involvement [27]. There is also a significant association between student involvement in student organizations and psychological development in the areas of establishing and clarifying purpose, educational involvement, career planning, life management and cultural participation [29]. Meaningful involvement is crucial for developing leadership skills [30]. In this regard, involvement experience is considered as training ground where students clarify personal values, learn about self and develop new skills [30].

The value of student organizations becomes more apparent at times of economic crisis. A downturn in the nation's economy influences the public universities in two ways: budget cuts and dropping student enrollments [31]. One potential solution to dropping student enrollment is recruitment and retention efforts being carried out by academic departments. It is also a proven strategy to utilize student organizations for recruiting new students and retaining current students [32]. Among many alternative recruitment strategies, Wasburn and Miller [33] demonstrated how to employ student organizations for recruitment purposes through on-campus workshops with families, hands-on laboratory experiences for prospective students, and participation in national conferences. There is a significant positive relationship between student involvement in student organizations and retention rates [27]. Moreover, it is considered by most faculty members that helping with student retention and student satisfaction is an important part of academic advising [34].

About the Student Association of Engineering Graphics and Design

The Association of Engineering Graphics and Design (AEGD) is a very active student organization on the campus of Murray State University. Although AEGD is comprised primarily of students in the Engineering Graphics and Design (EGD) program, it is not unusual to have student participation from other degree programs. The AEGD faculty advisor, supporting faculty and student advisors believe that the first and the most important goal is to retain and recruit as many EGD students as possible. For this purpose, a wide variety of activities are organized throughout the academic year to reach out to the new students. These activities are structured to promote interpersonal relationships and support between EGD students that will continue after graduation. EGD faculty believe that relationships and connections formed during involvement in AEGD create the foundation of a professional network. This professional network can be used as leverage in starting their careers. AEGD activities typically include meetings, industry trips, cookouts, wallyball games, video game nights, toy production and outdoor activities such as hiking, zip-lining, snow skiing and whitewater rafting.

Most of the aforementioned AEGD activities serve multiple purposes. For example, a wallyball is a fun activity that can help AEGD members by building and strengthening relationships, developing organization and team skills, and an opportunity to improve social skills. Likewise, industry trips serve as a means of extending classroom learning by exposing students to current trends in the profession, allowing interaction with industry professionals, and providing opportunities to market themselves for internships and full-time positions. Among all of the AEGD activities, toy production deserves special attention and analysis as it applies to authentic learning.

Method for Extracurricular Activities

Designing

Each year, AEGD students design, manufacture and sell approximately 150 wooden toys. This lengthy and multi-faceted process starts at the beginning of the fall semester with a club meeting. In the first meeting, new students are informed of the toy production project. Project process flow, goals and expected schedule of key steps are explained to the new students. The students are also instructed about the fundamentals of design and manufacturing processes, limitations and requirements of the final product. After setting the common rules and principles, students are assigned to find a toy design idea and bring a hand sketch to the next meeting. Figure 1 provides an example of a hand sketch. A typical toy idea is usually a vehicle, construction machinery or agricultural machinery.

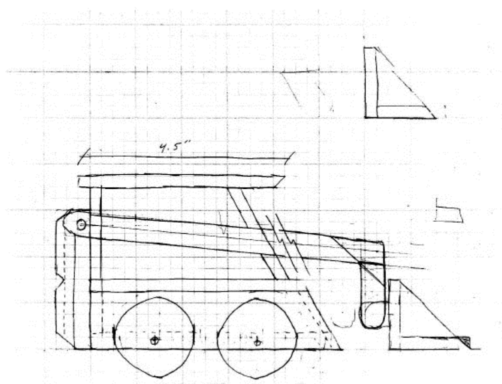

Figure 1. Hand Sketch of a Toy Idea

At the next meeting, all ideas and suggestions are analyzed and compared for initial design criteria. Usually, overall appeal and look, manufacturability and manufacturing time are considered for the final decision. At the end of the meeting, one toy idea is selected by a majority vote. The next step is to develop three-dimensional (3D) computer-aided design (CAD) models. Figure 2 provides an example of a 3D CAD model. Two or three modeling teams are assembled to generate alternative versions of 3D CAD models for the next meeting.

Figure 2. 3D CAD Model of a Toy Idea Created in SolidWorks

At the third design meeting, a more rigorous analysis is performed to select the best design among the provided 3D models. The initial evaluation is based on the manufacturability of the design in a limited period of time. The best time to sell toys is before the end of the fall semester, while the university is still in session. With Christmas being just a few weeks away, the toys are considered a nice gift by faculty, staff and students. Therefore, toy production has to be completed and on-campus sales must begin no later than the first week of December.

Considering a specific deadline, students are informed about the relationship between design and manufacturing. Students must consider the relationship between number of components and component sizes and features, and how they impact manufacturability and overall manufacturing time. At this point, faculty and students with previous toy production experience play a key role in finalizing the design. The design should be appealing to potential customers, easily manufactured and assembled, and engaging for the students who want to participate in toy production. The design evolves as students transition through various design iterations. Using parametric CAD software, a student applies changes to the 3D CAD model as other students follow the changes on the projector screen. The final design is completed by mixing and synthesizing characteristics of the alternative 3D CAD models.

Material selection and buy/make decisions are also discussed in the same meeting. Components can be purchased or made in the woodworking lab. Each part is analyzed for its manufacturability. If a component is impossible, time-consuming or unsafe to make with the available equipment in the lab, it is purchased. Toys usually consist of three or four different types of woods. Using different types of wood for the toys leads to contrasting colors. Contrasting colors assist in achieving better appearance and makes each part stand out on the final assembly. Purchased parts such as wheels, pins, caps and dowels are determined as part of the design decisions.

Rapid Prototyping

Following the approved design and dimensions, each component is manufactured on a fused deposition modeling (FDM) rapid prototyping machine. The prototyping process provides invaluable information about the toy design including size, appearance and ease of assembly. Figure 3 shows a toy design prototype. Based on the prototype, suggestions and any final design changes are made to the 3D model.

Figure 3. An Assembled Toy Made of Rapid-Prototyped Parts

Drafting

At this stage, individual component and assembly drawings are created for manufacturing. Drawings are dimensioned considering the capability of machining and measurement equipment available in the lab. The basic principle is to avoid using angular dimensions and inch fractions smaller than 1/16 of an inch. Thus, drawings are usually generated by junior and senior students with previous toy production experience.

Manufacturing

Before production starts, students are given safety instructions and properly trained on the use of the manufacturing equipment. At the beginning of the first manufacturing day, a summary-of-processes chart is created on a large whiteboard in the woodworking lab, which is visible and accessible by everyone. On the chart, each component is listed with its material specification, sequence of operations and required quantity. As the production progresses, the chart is updated at the end of each day to present the completed parts and processes and remaining work to be completed.

For the remaining three months, students and faculty work on producing 150 wooden toys in the construction lab, as seen in Figure 4. Usually, production sessions are scheduled for two consecutive days a week and last for four hours. During that time period, students work based on their availability.

Figure 4. Students Dipping Finished Toys into Toy Oil

Manufacturing is the process that makes the toy production experience different than previously mentioned typical design/build projects performed by student organizations. The design approach to a single unit final product is different than designing for mass production. A single-unit design project is more similar to a custom-made product in which the designing and building phases continue concurrently. Design always changes according to the mistakes, shortcomings or unexpected situations along the building stage. A student with good hands-on skills can implement solutions to these problems even if they make the design more complex or time consuming without the need of going back to the drawing table. Moreover, these projects are designed for competitions. Product characteristics such as speed, strength or durability are more important than feasibility, manufacturability or assemblability. For toy production, cost should be less than the sale price and the design should be easy to manufacture and assemble. In a real manufacturing environment, cost, complexity and production time are critical manufacturing parameters. For the toy production, these parameters are addressed at the design stage, because after production starts, changes can be difficult and costly to incorporate. Thus, designing, modeling and prototyping stages in toy production are more relevant to modern industry practices of today.

Toy production is also an educational opportunity to discuss material usage and process selection for manufacturing. A component can be cut by different machines in many different ways. However, safety, ease of production, material usage, waste, and finish quality depend on machine and process selection. Students are required to determine the amount of material required for each component as well as consider optimal manufacturing processes to achieve minimal waste.

After components are cut, sanded, assembled and oiled, the finished toy is ready to be sold. Figure 5 shows a finished wooden toy.

Figure 5. A Finished and Oiled Wooden Toy

Industry Trip

Students sell toys to faculty, staff and other students on campus. The money earned is used to finance an industry trip and cover expenses such as transportation, lodging and extracurricular activities. Spring industry trips are usually three-day-long trips to industry and amusement centers. On the first day, AEGD students visit one or two industries to experience real-world applications of design and manufacturing (see Figure 6). The next two days are spent engaging in outdoor recreational activities like skiing, hiking, white-water rafting and zip-lining. The spring industry trip is a combination of outside classroom learning and a reward for hard work on toy production.

Surveys

Faculty advisors believe that student involvement and empowerment are key requirements for a beneficial, positive club experience. Student approach and attitude towards the club and club activities are frequently monitored with casual conversations by the faculty. In the 2011-2012 academic year, two surveys were conducted to gauge student attitudes toward AEGD and toy production. The first survey was conducted at the beginning of the manufacturing phase of toy project. The main goal of the survey was to learn about the student expectations of and approach to toy production. Twelve students, who were present for the first toy production session, completed the survey. All participants were Engineering Graphics and Design majors. Among twelve students, all female students and one male student provided their GPAs. Background information of the participants is presented in Table 1.

Figure 6. An Industry Trip to Remington Arms Company

Table 1. Background Information of the Twelve Students that Participated in the First Survey

		Male	Female	Total
Class	Freshman	1	0	1
	Sophomore	0	0	0
	Junior	1	1	2
	Senior	5	4	9
Ave. GPA		2.9	3.4	3.3

The survey consisted of three open-ended questions, three yes/no questions, two questions regarding personal information and five response statements. Yes/no and open-ended questions were asked to gain information about the students' past participations in AEGD activities and their thoughts, expectations and suggestions about toy production activities. For the response statement questions, a five-point scale was used (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree). Statements and their corresponding mean values are given in Table 2.

Table 2. Statement Questions and Corresponding Mean Values for the First Survey

#	Statement	Mean
1	Building new friendships motivates me to participate in toy production	4.3
2	Socializing with the friends motivates me to participate in toy production	4.6
3	Building relationships with faculty motivates me to participate in toy production	4.5
4	Free spring trip motivates me to participate in toy production	4.8
5	I see the toy production as an opportunity to improve my design and manufacturing skills	4.6

From the statement questions, it can be concluded that students appreciate toy production for its educational, social and professional values. It is also significant to note that, with a mean value of 4.8, the possibility of a free spring trip is the highest-rated motivator to participate in toy production. This provides faculty with insight into the motivations as to why students decide to engage in toy production. For continuous success, it is crucial that students appreciate the organization and the activities surrounding it. A freshman EGD student summarizes his expectations as: "to get experience doing a full design and production of something, and get to know more people in my area for possible internships." In his answer, he summarizes many other students' answers and indicates the conformity between the club advisors' and students' vision and expectations.

The second survey was conducted in the last month of the academic year after all of the previously mentioned club activities were completed. The survey was completed at a club meeting by 16 Engineering Graphics and Design, one undeclared, one Civil Engineering Technology, one Manufacturing Technology and one Technology Education students. Among twenty students, two female and eight male students provided their GPAs. Background information of the participants is presented in Table 3.

Table 3. Background Information of the Twenty Students that Participated in the Second Survey

		Male	Female	Total
Class	Freshman	3	1	4
	Sophomore	0	0	0
	Junior	9	2	11
	Senior	3	2	5
Ave. GPA		3.2	3.2	3.2

The survey consisted of 13 statement questions with a five-point scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree) and a blank space under each sentence for students to express their opinion about the statement. Also, three open-ended questions were asked to gain information about the students' past participations in AEGD activities and their thoughts, expectations and suggestions about AEGD activities. Survey results are shown in Table 4.

Table 4. Statement Questions and Corresponding Mean Values for the Second Survey

#	Statement	Mean
1	Belonging to AEGD is important to me	4.5
2	I joined AEGD because my friends are in AEGD	3.4
3	I joined AEGD because it looks good on my resume	3.9
4	I joined AEGD because my advisor urged me to	4
5	AEGD has positively influenced me to stay in the program	4.3
6	Joining AEGD helps me to grow professionally	4.45
7	Joining AEGD helps me to grow academically	4.05
8	Joining AEGD helps me to strengthen leadership skills	4.1
9	Joining AEGD helps me to build a greater communications network	4.35
10	Joining AEGD helps me to strengthen my communication skills	4
11	I can relate AEGD "toy production" activities to professional life	4.25
12	I can relate AEGD "toy production" activities to the classes I'm taking	4.05
13	I don't participate in AEGD	1.95

Students were asked 13 statement questions to analyze their reasons for joining the club and participating in toy production. With a mean score of 4.5, all 20 students indicated that AEGD is important to them (Question #1). It should be noted that the faculty advisor has a major influence on the success of the student organization. The club advisor promotes, motivates and encourages member and non-member students to join the club and engage in all activities. The survey supports the significance of the advisor's efforts by a mean value of 4.0 (Question #4). With a mean score of 4.3, AEGD's positive effect on retention is also supported by the survey (Question #5). From the calculated mean values, it can be concluded that students have a high positive perception about the club and its possible benefits (Questions 6-10). Students value AEGD mainly for the academic, professional and social skills they develop as a result of participating in club activities. In regard to one of the open-ended questions, "what is the most beneficial thing about AEGD", the majority of students stated that networking opportunities, industry exposure and leadership development were key elements that made AEGD beneficial. Lastly, it is evident that, with mean values of 4.25 and 4.05, toy production has a constructive educational value for students (Questions 11 and 12).

Evaluation of AEGD Activities

Toy production is an opportunity for faculty members to engage students in authentic teaching/learning outside the classroom. Students appreciate the value of toy production from an educational perspective, as well. They realize how the concepts they learn in courses such as project management, scheduling, CAD modeling, dimensioning and design for manufacturability are applied to real-world scenarios. As shown by the student perception survey, year-long interaction fosters student/faculty relationships and assists in academic retention. As anecdotal evidence, from 2009 to 2012, six EGD students dropped out of school. These students had never participated in any club activity.

On- and off-campus recruitment efforts continue throughout the year. Recruitment activities consist of hosting high school students for competitions, educational tours and campus visits or introducing the program at a host high school through an hour-long presentation. AEGD students contribute to the recruitment activities by leading campus tours, organizing the activities, attending high schools and sharing their experiences with students.

During an academic year, AEGD students participate in numerous activities. Interaction between seniors and freshmen occurs naturally. Career-building connections and relationships established early in the freshman year can lead to internships or even full-time positions in the future. In 2012, graduates of the EGD program from two manufacturing companies visited the Murray State campus in order to interview junior and senior students for internship and full-time positions. Five full-time employees and three interns were hired by those companies. Over the year, faculty advisors spend more than 200 hours with the AEGD students. For faculty advisors, AEGD provides a valuable opportunity to monitor and help develop the professional skills of the students.

Conclusions and Discussion

As demonstrated by toy production, student organizations can be used as an educational tool. Every step of the activity has an educational dimension. From initial ideation sketches to selling toys on campus, students learn, practice and appreciate the concepts and skills they develop from their involvement in toy production. Sketching, design for manufacture modeling, drafting, detailing and dimensioning, manufacturing, waste reduction, project/time management and budgeting are all concepts that the students experience through toy production. It was also demonstrated that student organizations can help academic departments, programs and faculty members reach administrative goals. For recruitment and retention purposes, club activities should engage students and faculty throughout the continuation of the academic year.

Student organizations can be the starting point to establishing a professional network for students. Today, companies visited on the industry trips and past graduates are the main sources of internship and full-time positions for EGD students. The success of a student organization depends heavily on the efforts of advising faculty. The faculty advisor's role in a club constantly changes from that of leader to educator to friend and mentor. Having a positive impact on the academic, social and professional development of students is considered to be a part of academic advising responsibilities by the club advisors. However, creating a purposeful organization that engages students in meaningful, authentic learning can assist in skill development and prepare them for their respective careers.

Limitations

The surveys in this study are limited to the current students of the Engineering Graphics and Design program. A quantitative or a qualitative study can be performed to investigate the opinions of graduates and faculty members in search of EGD program and AEGD improvement as well as recruiting and retention rates. Research can be further extended with a pre-test/post-test design to analyze the association between club involvement and student development in academic, social and professional areas.

References

[1] Baker, C. N. (2008). Under-represented College Students and Extracurricular Involvement: The Effects of Various Student Organizations on Academic Performance. *Social Psychology of Education, 11*(3), 273-298.

[2] Milem, J. F., Berger, J. B., & Dey, E. L. (2000). Faculty Time Allocation: A Study of Change over Twenty Years. *The Journal of Higher Education, 71*(4), 454-475.

[3] Zhang, J. Z., Boysan, S., & Kashef, A. (2012). Preliminary Study on the Benefits of Virtual Reality Technology Supported by an Industry Partner to Enhance Manufacturing Education. *Technology Interface International Journal*, *13*(1), 5-13.

[4] Shim., E., Yoo, W. S., & Ngoma, D. (2012). Teaching Construction Scheduling Using a Simulation Game. *Technology Interface International Journal, 13*(1), 62-70.

[5] Breen, R., Brew, A., Jenkins, A., & Lindsay, R. (2004). *Reshaping Teaching in Higher Education: A Guide to Linkin Teaching with Research.* Routledge.

[6] Wenger, M. S., & Hornyak, M. J. (1999). Team Teaching for Higher Level Learning: A Framework of Professional Collaboration. *Journal of Management Education, 23*(3), 311-327.

[7] Tsang, A. K. L. (2011). In-class Reflective Group Discussion as a Strategy for the Development of Students as Evolving Professionals. *International Journal for the Scholarship of Teaching and Learning, (5)* 1.

[8] Dixon, R. A. (2012). Transfer of Learning: Connecting Concepts During Problem Solving. *Journal of Technology Education, 24*(1), 2-17.

[9] Katsioloudis, P., & Fantz, T. D. (2012). A Comparative Analysis of Preferred Learning and Teaching Styles for Engineering, Industrial, and Technology Education Students and Faculty. *Journal of Technology Education, 23*(2), 61-69.

[10] Supiano, B. (2012). College Enrollment Dropped Last Year, Preliminary Data Show. Retrieved from http://chronicle.com/article/College-Enrollment-Dropped/134928

[11] Martin, A. (2013). Downturn Still Squeezes Colleges and Universities. Retrieved from http://www.nytimes.com/2013/01/11/business/colleges-expect-lower-enrollment.html?_r=

[12] Vedder, R. (2012). Five reasons college enrollments might be dropping. Retrieved from http://www.bloomberg.com/news/2012-10-22/five-reasons-college-enrollments-might-be-dropping.htm

[13] Miller, M. R. (2011). Manufacturing Education: Evolving to Challenge Adversity and Public Sentiment. *Journal of Industrial Technology, 27*(2), 2-8.

[14] Narvais, L. (2009) Manufacturing Ranked #1 Industry for Economic Prosperity. Retrieved from http://www.nam.org/Communications/Articles/2009/06/ManufacturingImageRelease.asp

[15] Callahan, N., Jones, M. & Bruce, R. (2012). Best Practices and Success Factors in Online Education: A Comparison with Current Practice in Technology-Based Programs. *Technology Interface International Journal, 13*(1), 36-44.

[16] Rugy, V. (2011). U.S. Manufacturing: Output vs. Jobs since 1975. Retrieved from http://mercatus.org/publication/us-manufacturing-output-vs-jobs-197

[17] U.S. Bureau of Labor Statistics. (2010). Employment Projections. Retrieved from http://www.bls.gov/emp/ep_table_108.ht

[18] Giffy, C. A., & McNelly, J. (2012). Leadership wanted. U.S. Public Opinions on Manufacturing. Retrieved from http://www.themanufacturinginstitute.org/~/media/5856BC6196764320A6BEFA0D9962BE80.ash

[19] Somerton, C. W., & Genik, L. J. (2008). Advising Student Organizations: The Challenges (and Rewards?) for New Engineering Faculty. *Proceedings of the Annual Conference of ASEE.* Pittsburg, PA.

[20] Dolan, D. F., & Batchelder, M. J. (2001). Teaching Instrumentation through Solar Car Racing. *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition.*

[21] Sirinterlikci, A., & Kerzman, T. L. (2011). Active Learning through SAE Baja competition. *Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition.*

[22] Hay, M. E., & Pecen, R. (2005). Design and Implementation of Solar Electric Boats for Cleaner U.S. Waters. *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.*

[23] Maina, F. W. (2004). Authentic Learning: Perspectives from Contemporary Educators. *Journal of Authentic Learning, 1*(1), 1-8.

[24] Skinner, R. (1995) Authentic Assessment: Projects for the Future. *Proceedings of Conference of the Australian Science Teachers Association 44*. Brisbane, Queensland, Australia.

[25] Bennett, S., Harper, B., & Hedberg, J. (2001) Designing Real Life Cases to Support Authentic Design Activities. *Proceedings of the 18th, Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education.* Melbourne, Australia.

[26] Rule, A. C. (2006) Editorial: The Components of Authentic Learning. *Journal of Authentic Learning, 3* (1), 1-10.

[27] Huang, Y., & Chang, S. (2004). Academic and Cocurricular Involvement: Their Relationship and the

Best Combinations for Student Growth. *Journal of College Student Development, 45*(4), 391-406.

[28] Black, S. (2002). The well-rounded student. *American School Board Journal, 189*(6), 33-35.

[29] Foubert, J., & Grainger, L. (2006). Effects of Involvement in Clubs and Organizations on the Psychological Development of First-year and Senior College Students. *Journal of Student Affairs Research and Practice, 43*(1), 175.

[30] Komives, S., Longerbeam, S., Mainella, F., Osteen, L., & Owen, J. (2005). Developing a Leadership Identity: A Grounded Theory. *Journal of College Student Development, 46*(6), 593-611.

[31] Altundemir, M. E. (2012). The Impact of the Financial Crisis on American Public Universities. *International Journal of Business and Social Science, 3*(8), 190-198.

[32] Anderson-Rowland, M. (1995). Service Learning with Student Organizations. *Proceedings of the Frontiers in Education Conference*, Volume 2, Atlanta, GA.

[33] Wasburn, M., & Miller, S. (2003). Reaching Out to High School Girls: The Role of a Student Organization in Developing an On-campus Technology Workshop. *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.*

[34] Myers, B. E., & Dyer, J. E. (2005). Attitudes, Value, and Preparation of University Faculty and Administrators for Advising. *Journal of Agricultural Education, 46*(3), 35-46.

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Dynamical Systems Theory and System Dynamics: Educational Issues

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Abstract

The main theme of this study was to investigate the relationship between Dynamical Systems Theory and System Dynamics, and propose some ideas on educating undergraduate students in this area. It is suggested that "the essentials" of the former should be taught to establish a reasonable theoretical background, while teaching the latter. In this study, the roles and the relationship of Systems Theory and System Dynamics were first investigated within the body of Systems Thinking. This was followed by descriptions of a general framework and two courses designed for the purpose. The aim was to integrate the selected material from linear and nonlinear systems theory into System Dynamics Methodology. The resulting approach was in line with the multi-methodological trend seen in recent systems-oriented studies, and was expected to be quite effective in handling a certain class of systems.

Introduction

Interest in complex system studies has been growing rapidly in recent years; searching for better system paradigms or a combination of methodologies in a multimethodological framework is a part of this phenomenon. It is well known that General System Theory (GST) claims to be "the theory of theories", thus having the potential to resolve the dilemma of selecting and combining methodologies. However, GST does not provide well-defined guidelines in this respect. Although it has been successful in general terms, since its birth in the 1950s, GST has methodological limitations when it comes to dealing with specifics—it deals with general properties of systems, at an abstract level, regardless of physical form or domain of application, supported by its own metaphysics in systems philosophy [1], [2]. Both Systems Theory and System Dynamics are considered to be two of the major strands of GST, with the others being Operations Research (OR), Systems Science, General Systems Thinking, Systems Approach, System Analysis, Systems Engineering and Science of Complexity and Bionics. The Systems Thinking paradigm, primarily developed after the 1980s, includes quite a number of trends, including Critical Systems Thinking. The major concern of Critical Systems Thinking is how to make use of a variety of methodologies, methods and models available in a coherent manner to promote successful intervention in complex organizational and societal problem situations [3-6].

Jackson [3], [4] classifies all important systems methodologies providing critiques of all. His classification, from a social sciences point of view, includes the following groups: a) The Functionalist Systems Approach; b) The Interpretive Systems Approach; c) The Emancipatory Systems Approach; d) The Postmodern Systems Approach; and, e) Critical Systems Thinking. Selecting a particular methodology for a given system is not an easy task since all of these groups include various methodologies or approaches themselves. The two methodologies considered in this study, Systems Theory and System Dynamics (SD), both belong to the functionalist approach. The other major methodologies in this school are OR, Systems Engineering, Cybernetics, Living Systems Theory, Autopoiesis, and Complexity Theory, all including various approaches within themselves. Furthermore, the roots of System Dynamics are known to be in Systems Theory.

In the functionalist approach, systems appear as objective aspects of a reality independent of observers. Systems are studied using the methods of natural sciences to understand their behavior and use this knowledge to improve the efficiency or efficacy of the system—in "soft systems approaches" the primary concern is the multiple perceptions of reality and studying systems in a pluralistic environment. Within the functionalist approach, there is a group of methodologies where "hard facts" are used throughout the study, and this kind of approach is commonly referred as "Hard Systems Thinking". Systems Theory belongs to this category, providing theoretical background to methodologies such as OR, System Analysis and Systems Engineering. SD belongs to the Functionalist Systems Approach, but not to Hard Systems Thinking.

In regards to relating methodologies to problem contexts, Jackson [4] suggests that Hard Systems Thinking is applicable to "simple systems-unitary participant" types of problems. SD, on the other hand, together with Organizational Cybernetics and Complexity Theory, are suitable for "complex systems-unitary participant" situations. Further suggestions from Jackson are as follows: Soft Systems Approaches are applicable to both simple systems-pluralist participants and complex systems-pluralist participants; Emancipatory Systems Thinking is applicable to simple systems-coercive participants; Postmodern Systems Thinking is applicable to complex systems-coercive participants.

The methodology-problem context issue is also addressed by Kurtz and Snowdon [6], who developed a framework called the Cynefin sense-making framework, classifying systems as follows: Known, Knowable, Complex and Chaos. The Known systems are systems that have perceivable and predictable cause-and-effect relationships and can be handled via Sense-Categorize-Respond type methodologies (e.g., process re-engineering). In the Knowable category, cause and effect are separated over time and space, and Sense-Analyze-Respond type methodologies are suitable–Maani and Cavana [7] suggest that SD belongs to this category. Complex systems, on the other hand, are viewed as systems with cause-and-effect relationships that are coherent in retrospect and do not repeat; apparently, the appropriate methodologies for this category are the Probe-Sense-Respond type (e.g., pattern management). In chaotic systems, cause-and-effect relationships are not perceivable and can be handled only by the Act-Sense-Respond approach (e.g., crisis management). Although it is not possible to draw clear lines between different systems and different problem categories, the above suggestions help to develop a picture of where Systems Theory and SD stand, and what kinds of problems can be handled with them.

This study addresses the educational aspects of resolving problematic situations in the "complex systems-pluralist participants" category. This category corresponds to the Knowable area in the Cynefin sense-making framework. Although SD was more of a member of the complex systems-unitary participant category rather than complex systems-pluralist participants originally, the developments in the last decade moved it into the latter category. This paper is organized as follows: In the next section, the authors provide a brief discussion on the relationship between Systems Theory and System Dynamics. This section includes a critical review of Systems Theory and System Dynamics methodology, covering both "Hard Systems School" and "Soft Systems School" perspectives. After this, descriptions of the general teaching framework developed and the two courses designed are given. The concluding remarks and suggestions for future work are given in the last section.

The Relationship Between Systems Theory and System Dynamics

System Dynamics (SD) was developed by J. Forrester to overcome the inadequacies of conventional approaches, including Systems Theory, to enable systems scientist to deal with complex systems more effectively. In Systems Theory, system modeling is performed via mathematical tools, making the representation of "soft" issues quite difficult. Although SD modeling is based on the representation of systems via differential-difference equations, and positive and negative feedback loops similar to Systems Theory, SD methodology offers the capability of simulating non-analytical aspects of complex systems reasonably easily. Nonlinear, verbal and logical processes can be modeled without too much difficulty using software packages like IThink/Stella. Consequently, the system analyst is equipped with additional tools for modeling soft indicators such as human moral, burnout, commitment, loyalty, confidence and capacity for learning, etc. In organizational studies, for instance, modeling soft indicators in addition to conventional performance indicators like KPI (key performance indicator) and CSF (critical success factors) is vitally important. However, SD lacks the powerful tools of System Theory, due to the fact that its theoretical basis is weak. For instance, it is quite difficult or even impossible to conduct pre-simulation analyses and understand the structural properties of a system using SD; the analyst often has to try to foresee the consequences of certain decisions after some lengthy simulation studies, if and when possible.

Systems Theory has additional advantages over SD as far as structural analysis is concerned. In complex systems, the appropriate policy or strategy is developed often intuitively after examining all of the results of system analysis. Certain variables or a combination of variables are of special interest to the system scientist, quite often while others are of secondary interest. For instance, there are quite a large numbers of variables in an economic system, and one is usually interested in a few variables such as GNP, industrial production, inflation rate, etc. Such variables are normally grouped as system outputs. The way that inputs and outputs are connected in a system's structure provide an important perspective for system control. The input structure determines the degree to which the system's behavior can be modified, and the output structure determines the kind of information available for control. In Systems Theory, a system is said to be completely controllable if it is possible to drive the system from any initial state to another state within a finite number of steps. If the system is not completely controllable, then the system scientist either has to modify the control structure or base the design on the controllable portion of the system. Similarly, the dual concept of complete observability allows the system scientist to study the structural properties related to system measurement structure. It refers to the ability of inferring the system state by measuring the outputs. If the system is not completely observable, one then either has to modify the output or measurement structure, or employ an observer (an estimator in stochastic systems) to be able to determine (or estimate) the whole state vector. The system scientist loses all of these valuable structural analysis tools when using SD.

The shortcomings of the SD methodology have been addressed in the last decades, particularly in the 2000s. The developments in Hard Systems School and Soft Systems School have been influencing each other, creating richer versions of available methodologies and even new methodologies. As a result, quite significant developments in the capacity for hadling and managing complexity have been observed in various areas, including health, production and sustainability—particularly in the broad policy and strategy context where the wicked problems are. For instance, the contribution of Systems Thinking to the practice of OR (via Systems Approach, Complexity Theory, Cybernetics, SD, Soft OR and Critical Systems Thinking) is traced by Mingers and White [8]. Their major finding was that many of the core ideas of the systems approaches have been assimilated by other disciplines, where they continue to influence further developments, while other principles seem to have been forgotten, only to be periodically rediscovered or reinvented in different domains. In this context, they see the growth of the complexity theory as possibly the most significant development. Paucar-Caceres [9] explored similar issues within the context of MS/OR (management science/operations research). They look at both sides of the Atlantic and argue that American MS/OR has remained close to the positivist MS discourse, while the UK side has broadened its scope, establishing British MS soft and critical traditions. They think that the UK MS/OR community was succesfull in soft OR, but still needs to establish a bridge between theory and MS/OR practice by promoting multimethodology and multiparadigm approach.

Similar changes can be observed in the SD methodology; it has also been affected by Systems Thinking and the area of its applicability has been widened. Soft System Dynamics emerged along with various soft system thinking tools such as Checkland's Soft Systems Methodology, Soft Cybernetics and Soft OR [3], [4], [10], [11]. Soft SD enables system scientists to model soft issues more effectively and more realistically. However, unlike the works reported on OR-Systems Thinking, studies on the relationship between Systems Theory and SD are quite limited. Most of the published work on the theoretical issues in SD methodology are related to the modeling procedure and model validation.

The primary problem in modeling appears to be related to linking feedback loops and systems behavior via some formal tools. Groessera and Schwaninger [12] argue that most of the existing mental models in SD studies measure only parts of the system structure, and refer the system scientist to dynamical systems theory as the mathematical basis for SD to complement and validate the conceptual structure. The mathematical basis of SD is Systems Theory, as pointed out earlier in this study. This conceptual structure was explored by Kampman [13], where he studied the link between the System-theoretic and SD models. Kampmann attempted to establish this link between feedback loops and System behavior through the use of the "eigenvalue elasticity" concept. The idea is to apply tools from graph theory, formally linking individual feedback loop strengths to system eigenvalues. It helps analysts in understanding complex simulations by showing the usefulness of linear methods to nonlinear systems. On the same issue, Mojtahedzadeh [14] focused on consistency in explaining model behavior and model stucture, illustrating some of the issues related on three case studies; he calls for comparative studies on the subject. Stermann's [15] work is also related to this issue, but it is mainly concerned with structural validity, partial-model testing and over whole-model testing for structural adjustment.

It is widely known that SD models are often not validated thoroughly and they appear to be imprecise. They may also be based on poor data and ignore existing theories in the particular field. In fact, for most people working in Systems Theory, SD does not look scientific enough. Chaos Theory perspective even suggests that if SD models achieve sufficient precision and rigor, and are subject to proper validation procedures, they cannot predict the changes in response due to small changes in initial conditions. Jackson [3], [4] urges considerable caution in employing system dynamic (SD) models. The authors of this paper think this warning is important and still valid.

In general, the number of studies on the theoretical aspects of SD model building and validity is on the rise, but the theoretical issues involved are far from being resolved. In the practical world, the tendency for adopting an eclectic approach to multimethodological lementation can be observed. For instance, Morrison's [16] approach is quite a typical one. He uses two models to study the dynamics of managing process improvement; a formalized model to give the analytical solution, and an SD model to simulate the process. This particular application demonstrates how such models can be used practically, and effectively, in combination to understand the dynamics of a complex system. The authors of this paper are considering adopting a similar approach to expand the work reported by Temponi et al. [17], whose work reportedly combines several mathematical dynamic models of different business functions in order to obtain an aggregate model of an enterprise system to assist management's strategic decision making. This model can be complemented by an SD model in order to include soft indicators in a fairly realistic manner, relaxing the assumptions imposed by mathematical representation. Parallel use of these two models may bring some improvements in the overall operation of business systems. Similar arguments can be made for a recent study conducted by Ivanov and Sokolov [18] in which they address the operative perspective of supply chain dynamics through the use of control and systems theory. However, the links between these abstract models and the realities of supply chain systems remains to be resolved. This work can also be expanded via a multimethodological approach.

At this point, it is appropriate to look at INCOSE's (International Council on Systems Engineering) views on multimethodological approaches and the Systems Theory-Systems Engineering relationship. This study suggests that Systems Engineering lacks two essentials: 1) a fundamental systems engineering theory and principles on which the practice of Systems Engineering is based, and 2) inclusion of appropriate human, or people, engineering [19]. This is how Systems Engineering of 2020 is described in the vision developed here: The systems engineer of 2020 will develop expertise in the user domain and be able to address the social, economic and political impact of solutions. The education and training for systems engineers will focus on developing expertise in specific domains of interest, with an educational foundation in non-engineering disciplines such as sociology, psychology and economics. As a result, the systems engineer will have the requisite competence to work in a highly distributed and multidisciplinary environment with rapid access to a broad range of resources, and an understanding of human behavior and human-system interaction. The multidisciplinary and multimethodological approaches will certainly become more popular in the future. The book, Decision Making in Systems Engineering and Management [20], is a valuable work in the vision provided by INCOSE. It integrates new systems thinking tools into the conventional systems engineering lifecycle model fairly successfully—this book is one of the primary references used by the first author of this paper in systems-oriented courses.

The Proposed Teaching Framework

The two new courses designed at Ýzmir University are *Introduction to Dynamic Systems,* and *Systems Dynamics and Managing Complexity.* These courses will be offered primarily to Industrial Engineering students; students from other engineering departments and Business Administration/ International Trade and Finance will also be admitted. Due to lack of space, only the general aspects of the framework and summary of course descriptions are given here. Further details can be found in articles by Yurtseven and Buchanan [21], [22].

Systems Science basically provides a single vocabulary and a unified set of concepts applicable to practically all areas of science and engineering, bringing different academic disciplines together. In particular, Systems Theory, the core of Systems Science, makes use of mathematics, which provides an economy of language and establishes a conceptual framework for understanding the behavior of dynamic systems. Hence, the use of Systems Theory provides a far better understanding than the intuitive approach. Laware and Davis [23] examined the professional development of engineers from a systems thinking perspective. They view the mental model of systems thinking as a framework that can be utilized by students and professionals in professional development where Systems Theory serves as a tool to better understand economic and organizational change and processes. They suggest that students must develop a systems thinking approach to understanding their careers and to prepare themselves for the changing professional environment. Ropp [24] described the development of a safety management system within an aviation technology laboratory curriculum at Purdue University. Students are educated to view the associated system as a complex system; a system that places new demands and competency requirements on engineering and technology graduates in the aviation industry. The practical aspects of this systems-oriented education help students become competent in hazard identification, risk mitigation and proactive performance-based safety. Theuerkauf [25] stated that system theoretical considerations can help to convey engineering subjects and methods to students. He noted that viewing all technical systems from the point of view of material, energy and information and their modifications was a fairly strict technical approach in the past. He added that systems thinking has been expanded to include socio-technical aspects, hence its integration into secondary school and university curricula requires thinking in terms of systems and system models.

The differential and difference equation representations are the most common tools employed in representing dynamic phenomena or the time-evolutionary change. These equations represent the time linkages between various variables and allow one to study the interplay between the reality and the abstract. The vector notation of matrix algebra allows one to suppress the details, but retrieve them when needed. This is an effective and practical language, allowing the application of the theoretical results of linear algebra to large-scale systems. Markov chains, on the other hand, are employed to model dynamic systems that evolve probabilistically. All complex systems involve a fairly large number of variables, making them multivariable. Such systems can be observed everywhere, such as in population studies, economics, supply chain systems, ecological systems, etc. In representations, the large numbers of interrelated variables are seen as a whole set of relations in a complex system, suppressing the details.

What constitutes the essentials of systems theory obviously depends on one's perspective. In this study, they are identified by looking into the stages of SD methodology, in the general sense. The major steps of the methodology, as viewed by Maani ande Cavana, are as follows: Problem Structuring; Causal Loop Modeling; Dynamic Modeling; Scenario Planning and Modeling; Implementation and Organizational Learning [7]. Problem structuring or representation of dynamic phenomena is probably the most important step in the methodology. The powerful tools of Systems Theory, particularly Linear Systems Theory, can be employed effectively here. Due to the sound theoretical basis involved, the systems scientist or the student will feel comfortable in abstracting complex reality and developing a formal system model. As mentioned earlier, differential/ difference equation representations, matrix algebra and Markov chains can be used effectively to develop mathematical models of multivariable systems.

The preliminary analysis (stability, controllability and observability analysis) will be presented to students as described in Systems Theory. System stability will be introduced in the sense of Lyapunov, in the most general form as applied to nonlinear systems, followed by its results in linear system theory. Studying structural properties will help students to understand systems' behavior without going through complex simulation runs. Since the theory applies to all kinds of systems, students will see that one does not need to study one particular problem with set parameters. Furthermore, exploration of system structural properties will help to get some initial ideas on how realistic the models are. After developing some feeling about a system's behavior, students will be ready to relax some significant constraints imposed on the model and build an SD model of the system under study. Comparative response studies will allow them to improve the SD model and possibly the theoretical model as well.

In the generation of the solutions phase, students will observe the time variation of variables for various purposes, such as for planning, control, etc. They will realize that a specific solution can sometimes be found in analytical form, but more often with simulation. However, they will also see that simulation studies have obvious limitations; the number of experiments conducted by implementing different combinations of changes in the controlled variables, parameters and assumption often exceed practical levels. They will appreciate the fact that, the analytical techniques, when applicable, can provide valuable insight into the behavior of a system. Furthermore, they will realize that the influence of selected system parameters or operational policies on solution can be studied via some auxiliary concepts (stability, controllability and observability) in the exploration of the structural relations phase. Here, they will appreciate the use of different models in parallel.

The analysis conducted thus far will give students the opportunity to develop an intuitive insight into the system's behavior and foresee the possibilities for behavior modification. Normally, the suitable modification or control policies or strategies are determined after completing all of the studies summarized, intuitively in most cases. In the control or modification phase, students will attempt to change the system's response to an expected stimulus either by changing model parameters or introducing new connective mechanisms in the system. For instance, they will experience behavior modification by changing the birth rate in a population, or by changing production policy in a production system. They will also get a chance to work on more complex problems such as developing more effective policies through control after forecasting future trends in a macroeconomic model. At this point, students will be introduced to optimization, optimal control in particular, but only at a conceptual level; there will be no time for a detailed treatment. They will learn how to select the system input functions so as to optimize (maximize or minimize) an objective function (a measure of the quality of the system's behavior), leaving the rest of the work to computer software. They will be constantly reminded that mathematics serves as a language for organized thought; it should not be seen as a tool to generate the best policy or strategy.

Nonlinear System Analysis is also an important aspect of this framework. It will help students to establish a reasonable theoretical background and relate Systems theory to SD, since most SD models are nonlinear. Students will appreciate the value of SD when dealing with highly complex systems. Also, with a fairly strong theoretical background, they will be in a better position to interpret the results obtained from an SD study. They will realize that analysis of nonlinear systems is similar to that of linear systems in some respects, but different in other aspects. They will see that entirely different new types of behavior can be seen in nonlinear systems, as contrasted to linear systems. This phenomenon will be demonstrated on typical nonlinear systems such as the logistic curve and the finite escape time—the former is used to model exponential growth, often modified to reflect crowding, limited resources, etc., while the latter is a model of the growth process, where growth rate increases with size. They will also see that explicit solutions are rarely available in nonlinear systems, but it is possible to approximate or bound them with linear models, hence they will learn linearization. Here, they will learn the role of a summarizing function in characterization of systems behavior in broad terms. These concepts will be demonstrated on examples such as economic systems, studying equilibrium points, stability associated growth rates, predicting behavior resulting from perturbations in stimulus, characterizing limiting behavior, studying finite time escape phenomenon, saturation effects, threshold effects, etc.

The two courses designed to teach the above approach are briefly described now. Introduction to Dynamic Systems course has the following objectives: 1) to introduce the history and fundamentals of systems thinking and dynamic systems; 2) to teach analytical modeling and analysis of dynamic systems via various techniques; 3) to teach the essentials of linear systems theory; and, 4) to show the basics of nonlinear system analysis. The learning outcomes of the course are determined as follows: Through this course, students will learn the history, the main concepts and the major trends in systems thinking. They will appreciate the value of systems theory and its analytical power, and see how this theoretical framework can be extended to more complex systems. It is expected that the theoretical framework provided will help them to develop a deeper insight into the behavior and regulation of highly complex systems. The course includes the following topics: Historical Development of Systems Thinking; Classifications of the Major Strands in Systems Thinking; System Methodologies and Problem Context; Introduction to Dynamic Phenomena; Linear Systems Theory (modeling systems via differential/difference equations, linear algebra, and Markov chains, and concepts of control, controllability, observability, observers, estimators, and optimal control); and, Basics of Nonlinear System Analysis. The learning outcomes and their measurement process are given in Table A.1 in the Appendix; the table is summarized from the course ECTS (European Credit Transfer and Accumulation System) forms.

Concluding Remarks and Suggestions for Future Work

The main message to be delivered to students via these courses is that design and operation of today's systems require a certain amount of knowledge and skills of systems thinking. Students should be made aware of the fact that almost all systems are socio-technical in nature; whether they are dealing with a manufacturing system or a service system. Such systems cannot be handled by conventional thinking and tools; they tend to be messy and may require teams that involve engineers, managers, experts in finance, sociologists, psychologists, computer scientists, political scientists, etc., at various stages of the systems lifecycle. Systems thinking provides a common language, a set of system concepts, and a set of system methodologies to be able to deal with such complexities. Students should be prepared so that they can select and implement more than one methodology to analyze/design a complex system. The multimethodological approach developed in this study, via the combined use of Systems Theory and System Dynamics, is expected to provide students or system scientists with relatively more powerful tools in handling complex systems.

The potential areas for further work are as follows: 1) The framework and the courses will be updated as more information becomes available in SD methodology and its applications. There are an increasing number of research studies on the use of feedback loops and SD model validation. Also, cognitive aspects of modeling appear to be one of the important areas for improvement, and 2) Two more courses will be designed via a similar approach. The first one will be entitled "Fundamentals of Systems Engineering" and the second one will be related to Systems Engineering Management topics. The former will be a compulsory course for industrial engineering students in their fourth year (an elective course for other engineering students), and the second one will be an elective course for all engineering students.

References

[1] Skyttner, L. (2001). *General Systems Theory: Ideas & Applications*. World Scientific Publishing Co., Pte. Ltd., Singapore.

[2] Skyttner, L. (2006). *General Systems Theory: Problems-Perspectives-Practice, Second Ed.* World Scientific Publishing Co., Pte. Ltd., Singapore.

[3] Jackson, M. C. (2000). *Systems Approaches to Managemen*t. Kluwer Academic/Plenum Publishers, New York, NY, USA.

[4] Jackson, M. C. (2003). *Systems Thinking: Creative Holism for Managers*. John Wiley & Sons Ltd., Chichester, West Sussex, England.

[5] Flood, R. L., & Carson, E. R. (1998). *Dealing with Complexity: An Introduction to the Theory and Application of Systems Science*. Plenum Press, New York, NY, USA.

[6] Kutz, C., & Snowden, D. J. (2003). The New Dynamics of Strategy: sense-making in a complex-

complicated world. *IBM Systems Journal, 42*(3), 462-483.
[7] Maani, K. E., & Cavana, R. Y. (2007). *Systems Thinking and System Dynamics: Managing Change and Complexity*. Pearson-New Zealand.
[8] Mingers, J., & White, L. (2010). A review of the recent contribution of systems thinking to operational research and management science. *European Journal of Operational Research*, *207*, 1147–1161.
[9] Paucar-Caceres, A. (2010). The development of management sciences/operational research discourses: surveying the trends in the US and the UK. *Operational Research Society*, *109*. doi:10.1057/jors.2010.
[10] Checkland, P. (1990). *Systems Thinking, Systems Practice*. John Wiley & Sons Ltd. Chichester, West Sussex, England.
[11] Checkland P., & Scholes, J. (1993). *Soft Systems Methodology in Action*. John Wiley & Sons Ltd. Chichester, West Sussex, England.
[12] Groessera S., & Schwaninger, M. (2012). Contributions to model validation: hierarchy, process, and cessation, *Systems Dynamics Review*. doi: 10.1002/sdr.1466.
[13] Kampmann, C. E. (2012). Feedback loop gains, *System Dynamics Review*, *28*(4), 370–395.
[14] Mojtahedzadeh, M. (2011). Consistency in explaining model behavior based on its feedback structure, *System Dynamics Review*. doi: 10.1002/sdr.
[15] Sterman, J. (2012). Archives: Partial-model testing as a validation tool for System dynamics (1983). *System Dynamics Review.* DOI: 10.1002/sdr.1478.
[16] Morrison, J. B. (2012). Process improvement dynamics under constrained resources: managing the work harder versus work smarter balance. *System Dynamics Review, 28*(4), 329–350.
[17] Temponi, C., Bryant, M. D., & Fernandez, B. (2009). Integration of business function models into an aggregate enterprise systems model, *European Journal of Operational Research*, *1999*, 793–800.
[18] Ivanov, D., & Sokolov, B. (2013). Control and system-theoretic identification of the supply chain Dynamics domain for planning, analysis and adaptation of performance under uncertainty. *European Journal of Operational Research*, *224*, 313–323.
[19] INCOSE Systems Engineering Vision 2020. (2007). Technical Product, INCOSE-TP-2004- 004-02 September, 2007, Technical Operations–International Council on Systems Engineering. (INCOSE), San Diego, CA, USA.
[20] Parnell, G. S., Driscoll, P. J., & Henderson, D. L. (2008). *Decision Making in Systems Engineering and Management*. Wiley & Sons. Inc., New Jersey, USA.
[21] Yurtseven, M. K., & Buchanan, W. W. (2011). Introducing Systems Thinking and Systems Practice into Undergraduate Programs, *ICECE'2011-VI International Conference on Engineering and Computer Education, IEEE,* Portugal, 2010. *Proceedings, Procedia Social and Behavioral Sciences, 2*, 501–506.
[22] Yurtseven, M. K., & Buchanan, W. W. (2012). Educating Undergraduate Students on Systems Thinking and System Dynamics. *Proceedings, PICMET'12,* July 29 - August 2, 2012, Vancouver, Canada.
[23] Laware, G., & Davis, B. (2006) Systems Thinking: A Paradigm for Professional Development, *The International Journal of Modern Engineering*, *6*(2).
[24] Ropp, T. D. (2008) Implementing Safety Management Systems for Aviation into an Aviation Technology Curriculum, *Proceedings of the 2008 IAJC-IJME International Conference, ISBN 978-1-60643-379-9.*
[25] Theuerkauf, W.E. (2006) Technology Development and Technological Education, *Proceedings of the 2006 IJME-INTERTECH Conference.*

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Appendix – ECTS Forms

Table A.1 ECTS Form to Measure Course Learning Outcomes

No	Program Qualifications / Learning Outcomes	Level of Contribution				
		1	**2**	**3**	**4**	**5**
1	Ability to apply the acquired knowledge in mathematics, science and engineering			b		a
2	Ability to identify, formulate and solve complex engineering problems				a	b
3	Ability to accomplish the integration of systems			a	b	
4	Ability to design, develop, implement and improve complex systems, components, or processes			a	b	
5	Ability to select/develop and use suitable modern engineering techniques and tools			a		b
6	Ability to design/conduct experiments and collect/analyze/interpret data				a	b
7	Ability to function independently and in teams				a	b
8	Ability to make use of oral and written communication skills effectively			a		b
9	Ability to recognize the need for and engage in life-long learning				b	a
10	Ability to understand and exercise professional and ethical responsibility			a	b	
11	Ability to understand the impact of engineering solutions				a	b
12	Ability to have knowledge of contemporary issues				a	b

- (a) Introduction to Dynamic Systems; (b) Systems Dynamics and Managing Complexity.
- Grading catagories:
  1=Lowest, 2= Low, 3=Average, 4=High, 5=Highest

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