IMPROVING ENGINEERING TECHNOLOGY CURRICULUM THROUGH THE IDENTIFICATION OF EFFECTIVE MOTIVATIONAL STRATEGIES AND TEACHING APPROACHES

Tabitha L. Sprau Coulter, Ph.D.

Associate Professor of Civil Engineering

King's College

Abstract

With the many demands placed on students and the stringent requirements established by the Accreditation Board for Engineering and Technology (ABET), undergraduate engineering and engineering technology programs are overflowing with challenging, required courses. The program requirements are intended to better prepare graduates for the diverse technical and social skills necessary to succeed. However, students have complained current curriculum does little to contextualize engineering material and provides inadequate real-world learning opportunities. A lack of curriculum flexibility, increasing awareness of the difficult nature of engineering course work, and concerns surrounding student retention have contributed to higher education questioning whether or not traditional teaching approaches are effective.

The research study collected data on students' perception of the effectiveness of various teaching approaches and motivational strategies. The study also collected data on students' perception of the importance of receiving instructor feedback. The intention of the study is to gauge the effectiveness of various motivational strategies and teaching approaches and to identify specific areas where faculty should focus their classroom efforts. Upon completion of a traditional 3-credit, 15 weeks, face-to-face engineering technology course; students completed a 19 question survey where they evaluated the success of various learning opportunities that were incorporated into that particular course. All survey participants had the same professor who provided each of the six courses included in the study with the same types of learning opportunities. The data was compiled to identify if students consistently identify specific motivational strategies or teaching methods as effective techniques for learning new material. Through the study, it was identified that students value opportunities to contextualize course material, and perceive timely, faculty feedback as having a positive impact on their ability to learn the material.

Introduction

Undergraduate engineering and engineering technology programs have a long standing reputation for their challenging curriculum requirements. The demanding degree requirements are intended to better prepare graduates for the diverse technical and social skills necessary to

succeed in the engineering profession. Successful practicing engineers have a combination of technical, high-level, problem solving skills and soft skills. Additionally, practicing engineers are required to have a broad knowledge of general engineering content along with a mastery of specific skills. With the many demands placed on engineers and the rigorous requirements established by the Accreditation Board for Engineering and Technology (ABET), undergraduate curriculums are overflowing with required courses.

Issues with declining interest in pursuing engineering degrees coupled with some programs having inadequate industry connections have contributed to retention problems for many engineering programs [1]. A lack of curriculum flexibility, increasing awareness of the difficult nature of engineering course work, and issues with student retention and success rates have contributed to higher education questioning whether or not traditional teaching approaches are effective. Could inventive teaching approaches be implemented to help improve student learning outcomes and maintain student motivation?

Table 1: Dimensions of Learning and Teaching *[2]*

Preferred Learning Style		*Corresponding Teaching Style*	
sensory / intuitive	perception	concrete / abstract	content
visual / auditory	input	visual / verbal	presentation
inductive / deductive	organization	inductive / deductive	organization
active / reflective	processing	active / passive	student participation
sequential / global	understanding	sequential / global	perspective

When trying to better align classroom interactions with student needs, the topic of learning styles is often deliberated. Students learn in a variety of ways and many students gravitate to specific learning styles. These learning preferences influence which aspects of the learning process students will rely on. Most students have specific learning preferences they will seek regardless of the task they are trying to accomplish [3]. According to the Felder-Silverman model, there are multiple dimensions of learning styles. Each of the dimensions consists of two opposite categories or learning styles: active vs reflective, sensing vs intuitive, visual vs verbal, inductive vs deductive, and sequential vs global [2]. One outcome of these early studies was the documentation of the learning styles preferences of undergraduate engineering students. Early engineering education research helped in identifying learning style preferences, while attempting to address the gap between preferred learning styles and actually teaching styles being employed in engineering courses. Table 1 shows initial attempts to align learning styles preferences with teaching styles [2]. While many researchers have spent time trying to contextualize how students learn, little has been done to improve teaching styles employed within engineering programs.

Advances in technology have contributed to colleges exploring alternate learning opportunities including online learning experiences. More colleges are offering online courses, with some offering degree programs that can be completed entirely online. Online learning opportunities provide students with more time flexibility and the ability to tailor their learning experience to meet individual needs [4]. However, some individuals debate if online learning is appropriate for all degree programs and whether or not it accommodates all learning styles. Many argue it is difficult to accomplish necessary learning objectives and to accommodate engineering student's learning preferences in an online learning environment [5]. Some studies have described the "informal learning and the participatory culture of the internet" [6] as contributing to some of the disruptive challenges educators and students now have to deal with [6]. The lack of alignment between online learning and opportunities for project based learning has compounded existing curriculum challenges.

While educators recognize the issues associated with using traditional teaching styles for engineering education, many engineering programs still predominantly rely on traditional teaching methods. Educators have cited a lack of incentives to explore other teaching methods, a sense of comfort and familiarity with current teaching styles, and a lack of understanding what an improved teaching method would look like as barriers limiting their lack of exploration into alternative teaching methods [7]. Programs, like the Electrical Engineering, Mechanical Engineering and Naval Architecture in Split, Croatia, have documented issues with low student retention rates. They have documented that a lack of alignment between courses, teaching approaches and real world engineering applications has resulted in students who have low motivation to complete their studies [8].

In an effort to better understand how to enhance motivation within engineering curriculum, previous studies have explored methods to mitigate aspects of the engineering curriculum that attribute to student stress. One study explored non-traditional grading techniques and methods, such as the use of online learning management systems, that help students manage their own course content and knowledge acquisition [9]. Many engineering students cite grades as one of the most stressful aspects of their coursework. The mastery grading technique shifts the emphasis to ensuring that students are able to demonstrate mastery of the course learning outcomes. This grading approach requires students to thoroughly reflect on faculty feedback, to be engaged within their learning experience, and to retake exams until they achieve satisfactory performance [9]. Other studies have focused on understanding the impact of various motivational techniques in the context of specific, highly technical engineering topic, such as thermodynamics. Early data from one such study documented "identification with academics" and "attainment value" as leading factors that motivated students in a thermodynamics course [10]. Within this study, "identification with academics" related to students receiving a good grade and learning the material and "attainment value" related to the level of effort the students put into the course [10].

Some studies have also explored how engineering students' motivation changes over time, specifically over the course of their undergraduate studies. One study used a survey titled "Motivation and Attitudes in Engineering (MAE) Survey" to collect data on how seven different factors contribute to motivating students over the course of their undergraduate engineering experience [11]. The study observed a decrease in motivation in some of these areas. A

significant decrease was observed for "Mastery Approach and Expectancy" while a slight decrease was observed for "Perception of the Future" was observed [11]. The authors cited "more negative views" about pursuing a career in engineering and a decrease in being motivated by future goals as potential factors contributing to the survey results [11]. The study was effective at demonstrating that motivation is not static and also helped to validate the importance of understanding how to maintain student motivation in engineering education.

The research presented within this study will compliment some of the previous research that has focused on motivational strategies within engineering curriculum. Most previous studies have focused on understanding motivational strategies in the context of a specific course or engineering subject within engineering curriculum. While there is a lot of overlap between engineering and engineering technology, there are also some distinct differences. According to ABET's website:

> ". . . Engineering programs often focus on theory and conceptual design, while engineering technology programs usually focus on application and implementation. Engineering programs typically require additional, higher-level mathematics, including multiple semesters of calculus and calculus-based theoretical science courses, while engineering technology programs typically focus on algebra, trigonometry, applied calculus, and other courses that are more practical than theoretical in nature [12]."

Engineering technology programs tend to focus more on how to apply knowledge with reduced mathematical complexity. The research presented will look at students' perception of various teaching techniques and motivational strategies within several different upper level courses housed within an engineering technology department.

Experimental Approach

Faculty members in engineering and engineering technology departments are constantly faced with the difficult task of covering what some have argued should be 5 or 6 years' worth of course work into a 4-year bachelor of science (B.S.) program. This problem is compounded by pressure to meet ABET requirements, contextualize course content, offer engaging project-based learning experiences and maintain student motivation. With time limitations, faculty members have to be strategic with their use of classroom time and out of class assignments. The study presented was intended to understand what strategies students found most motivating and most effective for learning course material.

The Civil Engineering Technology (CET) department at SUNY Alfred State College of Technology has issues with maintaining student motivation and was exploring ways to better understand their students. The survey questions were developed through a collaborate effort lead by the professor who administered the survey within their classes. The survey was reviewed by the CET department faculty and vetted through the institutional review board (IRB). The survey was broken down into three sections that reflected areas where the department wanted to better understand their students: strategies for motivating students to complete course work and engaging with course material, effective strategy for learning the material, and benefit of timely faculty feedback. The first section, Questions 1 – 7, of the survey focused on understanding what learning activities motivate students and how the students felt about engaging with the material in various ways. The second portion, Questions 8 – 17, were intended to gauge how

effective the various strategies were for actually learning course material. The final section of the survey, Questions 18 – 19, was intended to gauge the importance of faculty feedback. Each of the three sections had a place for students to write in an additional question, along with a place for them to make comments and elaborate on responses.

All survey participants were enrolled in upper level courses housed within the CET department. The students in the survey were a combination of civil engineering technology and architecture students who needed the courses to fulfill degree requirements. Survey participants had the same professor and students were offered a similar assortment of opportunities to learn and engage with the course material. The survey participants were all enrolled in a course where learning outcomes were developed in accordance with ABET [13] requirements. The professor employed some traditional teaching strategies which included assigned course readings, and traditional lectures. In addition, the professor implemented interactive online learning experiences and assessment, opportunities for project based learning, in-class group work and group think-pair-share assignments, projects structured around peer competition, and opportunities for positive recognition in front of peers. Throughout the duration of the semester, detailed feedback on homework, quizzes, projects and exams was available within 24 to 48 hours of submission.

Upon completion of the 15-week 3-credit course, students voluntarily completed the survey titled "Effectiveness of Motivational Strategies and Teaching Approaches." The survey data reflects students' enrolled in three different civil engineering technology courses, with two sections of each course included in the study. The courses included were two structural analysis courses with a large calculation component (CIVL 4103 Structures I and CIVL 5213 Foundations and Concrete), and one course that focused on building systems (CIVL 6123 Mechanical Systems). Student's grades were calculated using a variety of different forms of assessment which included weekly homework assignments, quizzes, online activities, exams, individual and group projects, and class participation. The students were aware of the purpose of the survey and how the data would be utilized. Students provided consent prior to completing the survey, which was anonymous, optional, and had no influence on the students' grades. Hard copies of the survey were disseminated in person at the end of a lecture during the final week by the professor, who promptly left the room after the surveys were distributed. A student representative collected the survey responses and returned the completed documents in a sealed envelope to the professor who compiled the results after the semester had concluded.

Survey Data and Analysis

The survey consisted of a series of statements and employed a 5 point, bipolar scaling method. When responding to each statement, a score of 1 corresponded to does not motivate me / is not effective, 5 corresponded to highly motivates me / is very effective, and 3 provided survey participates with a neutral response option. Each question also had a "No Response or N/A" option for statements summarizing learning opportunities that students elected not to participate in or questions that the students chose not to complete. For instance, all students were assigned weekly readings, but only some students completed the reading assignments. Similarly, all students worked on the in class assignments but some elected not to share their work in front of their peers and only a small number of students (approximately 10) chose to participate in

presenting their work at the campus-wide "Student Showcase" event. While all students were provided with detailed feedback on submitted work, not all students read through and took advantage of the faculty feedback.

Table 2: Survey Responses

	N	N*	Mean	StDev	Distribution of Survey Responses
Q1	76	0	4.63	0.63	
Q2	74	2	4.38	0.93	
Q3	74	2	3.00	1.23	
Q4	76	0	4.31	0.87	
Q5	75	1	3.23	1.53	
Q6	76	0	3.96	1.08	
Q7	74	2	4.77	0.48	
Q8	76	0	4.49	0.81	
Q9	76	0	3.91	1.02	
Q10	76	0	4.53	0.72	
Q11	72	4	4.11	1.00	
Q12	76	0	4.51	0.70	
Q13	71	5	3.16	1.22	
Q14	75	1	4.01	0.98	
Q15	75	1	3.87	0.97	
Q16	76	0	4.07	1.01	
Q17	68	8	3.80	0.97	
Q18	76	0	4.88	0.49	
Q19	76	0	4.89	0.39	

A total of 76 students completed the survey, which represents approximately 80% of the total number of students enrolled in the six courses. The 76 students who completed the survey was distributed relatively equal between the courses included in the study. The students responded to the 19 survey questions using a 5 point bipolar Likert scale. They also had the option to fill in a response for an additional 3 questions and to provide comments. A summary of the survey responses is provided in Table 2. Table 2 provides the mean, standard deviation, and number of responses received for each question, along with a graphical representation of the response distribution. As the table displays, each of the questions resulted in a mean response greater than or equal to 3. Approximately 23% of the individuals surveyed gave question 5, which pertained to being recognized in front of their peers, a score of 1. Over 93% of survey participants gave question 18 a score of 5. Survey questions 3, 5 and 13 received the lowest overall responses; while questions 19, 18, and 7 received the most positive student responses.

The following questions received the lowest overall score with over 50% of survey participants rating these questions 3 or lower:

- Question 3: I am motivated by opportunities to share/present work to classmates
- Question 5: I am motivated by recognition in front of my peers.
- Question 13: Assigned readings are helpful for learning course materials.

Questions 3 and 5 both focused on presenting and receiving reorganization or feedback from peers. While some students found these opportunities helpful, many found the situations stressful and felt they did not benefit from peer focused learning experiences.

The following three questions received the highest scores for being effective strategies for motivating students. Using the 5 point Likert scale, over 94% of the survey participants gave these questions a score of 4 or greater:

- Question 19: Receiving feedback in a timely manner is helpful because I want to know what I did wrong and how I can improve my understanding of the material.
- Question 18: Receiving grades in a timely manner is helpful because I want to know my grade.
- Question 7: I am motivated by the opportunity to learn material that will help my career.

The responses provided for Questions 18 and 19 demonstrate that students feel faculty feedback is an important aspect of their courses.

Results

Throughout the duration of the course, the professor observed that some of the teaching methods employed, such as peer competition and peer recognition, had a positive impact on maintaining student engagement and attention during lecture. Teaching strategies that encouraged student engagement included in class group work, and opportunities to present and receive recognition in front of peers. However, compared to some of the other teaching strategies, the students did not rank these opportunities as being particularly effective. The survey did not collect data on what students perceived to be effective methods for maintaining interest, however this would be an interesting topic to add to future studies.

One of the teaching methods that scored the lowest for teaching effectiveness was Question 13 which focused on assigned course readings. Assigned readings are intended to help students prepare for lectures, encourage interaction with course material and topics that are not covered in depth during lecture, and to reinforce lecture content. For many faculty members, assigned readings are used as the primary method for disseminating knowledge outside of the classroom. The question centered on assigned readings scored low with many students admitting they rarely complete the course readings. This was an interesting finding, as it helps to facilitate a discussion about whether or not faculty members should continue to assign readings. Some students elaborated on their response to this question stating that: “readings were long and uninteresting”, “were difficult to follow”, and that they “did not maintain attention.” If faculty members are going to continue to rely heavily on reading outside of the classroom, are there methods that could be implemented to help motivate students to engagement with the assigned textbooks? Are there other methods that would encourage students to engage with course content outside of the classroom such as case studies, blogs or videos?

The two questions on the survey that addressed recognition by peers and opportunities to share work with classmates also scored low. Engineers have a reputation for having poor communication and social skills. Completely eliminating collaborative group work and opportunities for students to present in front of their classmates is likely not an appropriate solution. However, this finding does prompt an important discussion about how we may better leverage these opportunities in a manner that students find it valuable rather than stressful. It should also be noted that some students eagerly volunteered to participate in these opportunities and reported the experiences as highly beneficial. While there was no identifying data collected, it is likely that those who enjoyed these opportunities were the same students who gave these

questions a score of 5 when completing the survey. It would be interesting to track student's perception of the value of group projects throughout their undergraduate education.

There were two questions on the survey about the importance of receiving instructor feedback. Both of these questions received very high student scores. In addition to giving these two questions very high scores, many students also wrote in comments about why they felt feedback was important. The comments revealed that students view feedback as an important component of the learning process, and as an opportunity to correct previous misunderstandings about course material. Many students also felt the timeliness of the faculty feedback was a reflection of the course instructor. Several students added comments that receiving feedback in a timely manner was: "an indication that the professor was doing their job," "showed that the professor cares about student success," and "demonstrates that the professor is also interested and invested in the course."

Out of the various teaching techniques that were utilized in the classroom and included in the survey, the techniques that allow students to contextualize material and learn skills that will directly help their career scored the highest. Due to the large amount of information that needs to be covered in undergraduate curriculum, a lot of material is taught at a high level, from a theoretical perspective. Students were more motivated and found it easier to learn the material when they could see the direct connection between course content and how they would utilize that knowledge in a real world setting. This finding supports the importance of providing project based learning opportunities throughout the entire four years of an undergraduate program and also demonstrates the importance of promoting industry connections.

Conclusion

Opportunities for closer connections between academia and industry have long been viewed as an important component of higher education. The study helped to demonstrate that students value these opportunities and the knowledge they gain from these experiences. The study also showed that with our quick paced society, students want timely feedback. The feedback is used as a way for students to understand how they are performing in a course and also motivates them to spend more time working on areas where they are struggling.

Another important observation from this study is that students are not using textbook resources to their full potential. Many of the students surveyed admitted that they rarely open their textbooks outside of using them to get assigned homework problems. However, the majority of engineering and engineering technology syllabi still have required textbooks listed; and many faculty members assign course readings. There appears to be a clear disconnect between how instructors want and think students are utilizing textbook resources, and how students actually are using these resources. While this finding may be frustrating to many faculty members, it can also be viewed as an opportunity to explore alternate resources. As mentioned earlier, there may be other interesting ways to either motivate students to engage more thoroughly with assigned readings; or opportunities to explore alternate resources to complement what is being taught in lecture.

Future research

The data collected focused generically on aligning students enrolled in engineering technology courses with motivational strategies. However, research has shown the importance of understanding individual students' learning personality profiles. While previous studies have classified the learning preference more engineering students gravitate towards, all students are different. Particularly in smaller class settings, it becomes increasing important to ensure teaching styles are tailored to meet student needs. In the future, I plan to expand on this study by attempting to align learning preferences with data on how students perceive the effectiveness of various teaching approaches and motivational strategies. Similarly, there would be benefit in looking at individual performance compared to learning opportunities students participate in. Research will also be conducted to explore alternates to assigned course readings. Professors would be able to use this information to be more strategic in deciding which motivational strategies and teaching approaches to incorporate into their courses.

References

[1] W. Wulf and G. M. Fisher, "A makeover for engineering education," *Issues in Science and Technology,* vol. 18, no. 3, pp. 35-39, Mar. 2002.

[2] R. M. Felder and L. K. Silverman, "Learning and teaching styles in engineering education," *Engineering Education,* vol. 78, no. 7, pp. 674-681, 1988.

[3] N. Entwistle and E. Peterson, "Learning styles and approaches to study," *Encyclopedia of Applied Psychology,* vol. 2, pp. 537-542, Nov. 2004.

[4] M. S. A. Mansor and A. Ismail, "Learning styles and perception of engineering students towards online learning," *Procedia - Social and Behavioral Sciences ,* vol. 69, pp. 669-674, Dec. 2012.

[5] D. P. Diaz and R. B. Cartnal, "Students' learning styles in two classes: Online distance learning and equivalent on-campus.," *College Teaching,* vol. 47, no. 4, pp. 130-135, 1999.

[6] R. Bass, "Disrupting ourselves: The problem of learning in higher education," *Educause Review,* pp. 23-33, 21 March 2012.

[7] S. E. Bradforth, E. R. Miller, W. R. Dichtel, A. K. Leibovich, A. L. Feig, J. D. Martin, K. S. Bjorkman, Z. D. Schulta and T. L. Smith, "University learning: Improve undergraduate science education," *Nature: International Weekly Journal of Science,* pp. 282-284, 15 July 2015.

[8] B. Blagojevic and M. Sikora, "Effectiveness of project-based learning in GIS course," in *Proceedings of the 10th Research/Expert Conference with International Participations "Quality 2017"*, Neum, 2017.

[9] L. T. Schlemer and L. Vanasupa, "Grading for enhanced motivation and learning," in *Proceedings of the 123rd Annual Meeting of American Society for Engineering Education (ASEE)* , New Orleans , Jun. 2016.

[10] R. McCord and H. M. Matusovich, "Developing an instrument to measure motivation, learning strategies and conceptual change," in *Proceedings of the 120th Annual Meeting of American Society for Engineering Education (ASEE)*, Atlanta, Jun. 2013.

[11] L. Benson, C. McGough, D. M. Kuzbary and J. L. Sharp, "Longitudinal study of changes in student motivation and attitudes in engineering," in *Proceedings of the Annual Meeting of American Society for Engineering Education (ASEE)*, Columbus, 2017.

[12] ABET, "New to Accreditation?: Engineering vs. Engineering Technology," Accreditation Board for Engineering and Technology, Inc., 2018. [Online]. Available: http://www.abet.org/accreditation/new-to-accreditation/engineering-vs-engineering-technology/. [Accessed 20 March 2018].

[13] ABET, "Criteria for Accrediting Engineering Programs," Engineering Accreditation Commission, Baltimore, MD, 2014.

Dr. Tabitha L. Sprau Coulter, King's College

Dr. Tabitha L. Sprau Coulter is an Assistant Professor of Civil Engineering at King's College where she is helping develop new civil engineering and mechanical engineering programs. She was previously a faculty member at SUNY Alfred State College of Technology where she taught in both the Civil Engineering Technology department and the Architecture and Interior Design department. She holds M.S. and Ph.D. degrees, both in Architectural Engineering from The Pennsylvania State University. Prior to working in academia, Dr. Sprau Coulter worked in engineering and energy consulting. While pursuing her Ph.D., she was an NSF Grant recipient and she was involved with the Navy Yard EEB Hub.