ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #36600

The Effect of Introducing Biological and Environmental Discipline-Themed Problems in Statics on Students' Self-Efficacy and Perceived-Value of the Course

Yemisi Victoria Oyewola (Graduate Research Assistant)

Victoria Oyewola is a graduate research assistant and a Ph.D. student in the Department of Engineering Education at Utah State University. She has a master's degree in information science and a bachelor's degree in Computer Engineering. Her research interests consist of investigating the soft skills acquisition of engineering undergraduate and graduate students. She is also interested in research related to engineering design thinking and engineering education professional development.

Brian Douglas Cowburn

Theresa Green

Dr. Theresa Green is a postdoctoral researcher at Utah State University with a Ph.D. in Engineering Education from Utah State University. She holds a B.S. in Mechanical Engineering from Valparaiso University and an M.S. in Mechanical Engineering from Utah State University. Her research interests include K-12 STEM integration, curriculum development, and improving diversity and inclusion in engineering.

Wade H Goodridge (Associate Professor)

Kurt Henry Becker (Engineering Education Professor)

Kurt Becker, Ph.D., Professor, Department of Engineering Education, College of Engineering, Utah State University Kurt Becker is a Professor in the Department of Engineering Education at Utah State University. His research includes engineering design thinking, systems engineering, engineering education professional development, technical training, and adult learning cognition. He is currently working on National Science Foundation funded projects exploring engineering design thinking and systems thinking, a USAID funded project in Egypt, "Center of Excellence in Water", and Department of Education funded GEARUP projects in the area of STEM education related to engineering education. He has extensive international experience working on technical training and engineering projects funded by the Asian Development Bank, World Bank, and U.S. Agency for International Development (USAID). Countries where he has worked include Armenia, Bangladesh, Bulgaria, China, Egypt, Indonesia, Macedonia, Poland, Romania, and Thailand. In addition, he has taught undergraduate and graduate courses in engineering education for the department.

Work in Progress (WIP)

The Effect of Introducing Biological and Environmental Discipline-Themed Problems in Statics on Students' Self-Efficacy and Perceived-Value of the Course

Abstract

Statics is a required course for the biological and environmental engineering majors, but it often focuses solely on mechanical and civil engineering applications. With no connection to their career, students often see a drop in performance and career development. Therefore, new problems from biological and environmental engineering disciplines are introduced into the course. This study examines the self-efficacy developed within students and the perceived value they ascribe to new problems that teach fundamental statics concepts and focus on biological and environmental principles. The study collected data from 133 students over three semesters. The effect of this intervention was measured by administering a pre-and post-survey at the beginning and end of the course to the Biological, Civil, Environmental, and Mechanical Engineering students found in the class. The surveys asked the participants to rate five questions about their self-efficacy and seven questions about their perceived value for the newly introduced homework problems. Ratings were conducted with a five-point Likert scale. Self-efficacy (SE) and perceived value (PV) were studied because of their correlation to performance and future career development. This is a work in progress, and there is an ongoing effort to continue to build the data pool of biological and environmental engineering students since the numbers of those that participated in the study are not large enough to empirically arrive at a conclusion. As such, this study will only be looking at the trend data for the biological end environmental engineering students. The change in the Mean for the SE pre (4.14±0.74) and post (4.10±1.03) data and PV pre (3.40±0.89) and post (3.62±0.73) data showed that there was an improvement in the PV of the course by the Biological and Environmental Engineering students after the new problems were introduced. SE did not reveal any significant difference. This also correlated with the trend in the mean for SE and PV for each individual semesters' survey. In addition to this, the Wilcoxon signed-rank test was used to find significant changes in the data for pre-and post-surveys ranking of the nonparametric data. The results indicated that there was a significant increase in students' PV of the course (pvalue = 0.003) while the SE was not significant (pvalue= 0.128). This study shows that even though authentic Biological and Environmental focused engineering problems have no impact on the students' self-efficacy, they still found the intervention valuable and helpful to their understanding of the course. This value was derived by adding Biological and Environmental engineering-focused questions to Statics and this implies that instructors can maximize the effectiveness of their instruction by implementing major-specific examples and assignments in their classes.

Keywords: Self-Efficacy, Perceived Value, Statics, Biological and Environmental Engineering

1. Introduction

Statics is a foundational engineering course that is typically taken in a student's second year for many engineering disciplines. This is a key time when students are evaluating if they should continue pursuing engineering or if they should change majors. Statics also provides knowledge for future engineering courses that build upon its foundational content, such as Strengths of Materials and Dynamics. A typical statics class is heavily focused on problems suited to mechanical and civil engineering students, which can leave biological and environmental engineering students with little understanding of how the concepts of statics are applied to their engineering discipline. Without having a connection with students' discipline in terms of content, it becomes difficult for them to understand the relevance of the subject being taught. As such, their motivation, self-efficacy, and engagement significantly decrease [6].

Meanwhile, self-efficacy, which is described as the confidence that someone has in his or her ability to complete a specific task has been linked to students' performance, such that students with higher self-efficacy perform better and vice-versa [2], [15], [16], [25]. This necessitates that educators take measures that could enhance the students' self-efficacy. Also, the perceived value, which is described as students' anticipated benefits and sacrifices with respect to the outcome of using educational tools or services has been said to have the ability to maximize the performance of a teaching method [1], [9]. This is because it is correlated with students' motivation and performance [10]. Thus, in an effort to enhance the self-efficacy and perceived value of students, problems that are specific to the biological and environmental engineering discipline were introduced into the Statics course and this study seeks to investigate how impactful this has been on the students' self-efficacy and perceived value.

Four new statics problems were developed that more closely align with biological and environmental engineering principles (see, Appendix I). These problems were then used in three different semesters: Spring 2020, Fall 2020, and Spring 2021 at High Rise University. Students were told about the research and the purpose of the newly designed questions. IRB protocols were developed and followed in recruiting participants. Pre- and post-surveys on self-efficacy and perceived value were administered to the students enrolled in the class with five questions measuring self-efficacy and seven questions measuring perceived value and were answered on a five-point Likert scale. These questions were asked once near the beginning of the semester before the introduction of the environmental and biological-themed questions and once at the end of the semester after the completion of the introduced questions. Extra credit was given to the students when they completed each survey. A principal components analysis (PCA) was run on a 12-question questionnaire that measured the self-efficacy and perceived value of 66 participants. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicated that the strength of the relationships among variables was high (KMO= 0.83), while Bartlett's Test of Sphericity was statistically significant (χ^2 (66) =641.83, $p < .0005$), thus indicating that it was acceptable to proceed with the analysis.

This study investigates the impact of statics homework problems developed around biological and environmental engineering applications on students' self-efficacy and their perceived value of the course. With the development of problems that align with biological and environmental

principles introduced into Statics class, the effect that the refocused problems have on students can be identified. To measure this effect, the student's perceived value of the problems and their self-efficacy were calculated from survey instruments administered before and after the introduction of the homework problems. Using this, along with demographic information such as the major of the student, statistical tests were used to determine if the newly developed problems had the intended effect on the biological and environmental engineering students.
The study specifically looked at the difference in the self-efficacy and perceived value on pre- and post-survey instruments and it should be noted that the study does not consider the grades of the students but only investigated how they felt about the course before and after the intervention of the biological and environmental engineering-themed problems.

2. Literature Review

2.1 Knowledge Retention in engineering

The knowledge retention of engineering students has been a known problem and still affects institutions today. Due to the significance of this problem, there have been many studies on engineering students' knowledge retention and its causes [4], [8],[11], [14], [19]. More recently, links have been drawn between engineering student retention and a feeling of community with a focus on problems relevant to the students' current engineering practice [20].

It has been said, that for any science, technology, engineering, and mathematics (STEM) class, teaching methods aimed at improving knowledge retention should expose students to real-world problems that highlight potential career opportunities [5]. In most statics classes, the problems are heavily focused on concepts that are traditionally found in civil and mechanical engineering, such as trusses and pulley systems. There are limited opportunities for biological and environmental engineering students to engage with real-world problems that demonstrate the relevancy of statics to their own disciplines. With an ever-growing need for these majors, a lack in the retention rate of students in the majors is detrimental to their self-efficacy and overall success in the disciplines as the knowledge of statics is one of the basics, they needed for their career success.

Therefore, it is necessary to re-envision the teaching of statics class because it is a required foundational course the biological, and environmental engineering students. It is believed that introducing major specific topics into this course will aid in the retention which should culminate to improvement in the self-efficacy of the students. Some researchers have tried to take a more project-based approach to teaching [3]. Others have tried to rearrange the order in which information is taught, while also taking a more physical approach to the class. For instance, Dollar and Steif [7] found it desirable to present information sequentially and in the context where forces could be perceived with sight and touch while Oerther [18] implemented an integration of biology into classes taken by other engineering majors. This latter study found that students appreciated the effort taken to integrate state of the art molecular biology into environmental engineering courses. Our research aims to combine these two endeavors to create biological and environmental-focused problems and integrate them into a statics class to improve student experiences.

2.2 Self-Efficacy

Self-efficacy has been defined as an optimistic self-belief and the extent to which one is confident that he or she can perform very well in difficult tasks and or cope with adversity, in various domains of human functioning, thereby resulting in a successful performance [2], [22], [25]. Self-efficacy being the confidence that someone has in their ability to complete any specific task is a very complex concept with many dimensions that has no generalizable instrument used for all situations. Self-efficacy generally has three dimensions: magnitude, strength, and generality. Magnitude describes the difficulty of a task someone believes they can complete. Strength relates to the extent to which the ability to complete a task is felt. Last, generality is whether someone feels they can complete a wide range of tasks confidently [23]. We set out to measure the self-efficacy of engineering students in their ability to solve statics problems. Self-efficacy has been studied within the context of education since 1986 when a multidimensional instrument was created to use among students, teachers, and principals [21].

Self-efficacy is a valuable concept to determine the success of various teaching interventions. Past research has linked self-efficacy to performance and future engineering interests [17]. Due to this link, it is an ideal construct to measure for this research because biological and environmental engineering students have limited opportunities in a typical statics class to develop future engineering interests due to the lack of relevancy of traditional statics problems.

2.3 Perceived Value

For this study, the definition of perceived value was described by how students view a given educational tool or intervention benefiting them and their future academic goals [9]-[10]. In market research, perceived value is calculated by the individual through an analysis of costs and benefits [24]. The extra effort a student puts into understanding an intervention or problem can be no greater than the clarity the intervention provides. This idea originates from market research in psychology journals, where the perceived value and quality of a product are related to the price a consumer would buy that product at. The concept of a trade-off between the cost of a product and its perceived value was later brought into education research [12]. Perceived value is becoming an increasingly popular metric to use in the classroom and higher education because of its ability to maximize the performance of a teaching method [1].

2.4 Social Cognitive Career Theory

To aid biological and environmental engineering students in their journey through higher education, it is important to look at theories such as Social Cognitive Career Theory (SCCT) so that constructs like perceived value and outcome expectations can be studied. SCCT is a useful way to describe the career development of students and people in the workforce in terms of their self-efficacy, outcome expectations, and goals [3]. SCCT is made up of three overlapping models, and in this context, the performance model is most relevant to the present study. The theory explains the following process, which is self-repeating throughout someone's life. First, current ability and past performance change both self-efficacy and outcome expectations of that person. Outcome expectations are someone's beliefs about how their current circumstance will impact their future. These two metrics then shape the goals that a person holds. Everything previously mentioned impacts the performance of that person in the future. The newly developed performance then affects the current ability of that person restarting the cycle [13].

For this study, the outcome expectations of a student are viewed as the perceived value of the intervention. How a student views the costs and benefits of a new problem will be the same as what they expect to get from the problem. This study focused on improving performance, hence the performance model, of biological and environmental engineering students by measuring self-efficacy and outcome expectations/perceived value.

The data collected from biological and environmental engineering students could only be analyzed using non-parametric statistical analysis due to the small number of the student's enrolment in the class during the three studied semesters. However, Major-specific results can only be seen in general trends from pre- to post-survey. Due to the non-parametric nature of the data a Wilcoxon signed rank test was used in place of a t-test to analyze the combined data from students across all engineering majors taking the class because.

3. Methods

3.1 Description of Methods

The research team began the process by developing new statics problems that would be within the difficulty level of the current problems, while simultaneously being particularly suited for biological and environmental engineering students. Engineering students that had previously taken statics were solicited to develop the problems since they were familiar with the course content. Once the problems were developed and approved, they were used as homework problems for the students. Some of these problems are Digital Pulley in Rock Climbing, Green Roof Truss, Reverse Osmosis, and Forces and Moments on Cervical Vertebrae.

As these problems were distributed over three semesters, surveys were conducted both at the beginning and end of the semesters, referred to as "pre- and post-semester" surveys. These surveys were built using a five-point Likert scale and included five questions that would be used to calculate each student's self-efficacy and seven questions that would measure their perceived value of the introduced problems. The pre-survey was conducted before the students were exposed to the new material but after instruction had started while the post survey was conducted at the end of semester. The students were also asked to provide their major so that the responses from students in the biological and environmental engineering majors could be compared to those in the mechanical engineering, civil engineering, and other majors that were in the statics class. After the survey instruments were complete, the reliability of the instrument was calculated with Cronbach Alpha test. The results from this test showed that the survey instrument was reliable so further analysis could be conducted.

Once the data was collected (pre and post), it was transferred into IBM's SPSS software to be analyzed. Between team members, SPSS version 21.0 was used. First, the majors were coded so that biological and environmental engineering majors were labeled as one group, and all other majors were labeled as a separate group. Then, by taking the statistical mean of the first five questions and then the next seven questions, we were able to calculate the self-efficacy and perceived value respectively. Then, a mean with standard deviation was created with self-efficacy and perceived value as the dependent variables, and the students re-coded major as the independent variable. This was done for each semester's pre- and post- data.

Next, the pre- and post- self-efficacy and perceived value data was compared within each semester using a Wilcoxon signed ranked test to determine the reliability and significance of the data. Lastly, the data for each semester's pre- and post- self-efficacy and perceived value were compiled into pre- and post- totals. Similarly, these totals were then run through the Wilcoxon test to determine the reliability and significance of the total data.

4. Student Demographics

Demographic Characteristics of the Respondents

The total number of students that participated in the pre and post survey for the three semesters was 133, with percentage distributions across the three semesters shown in Fig. 4.1. The percentage distribution of the demographics of all participants for both the pre and post survey are shown in Table 4.1.

Table 4.1 Demographic distribution of the participants.

Variables	Measurement	Pre-Survey	Post-Survey
Major	Mechanical Engineering	65.9	64.7
	Civil Engineering	16.5	18.0
	Biological Engineering	13.7	12.8
	Electrical Engineering	2.2	3.0
	Environmental Engineering	0.5	0.8
	other (please specify)	1.0	0.8
Sex	Male	80.8	77.4
	Female	19.2	22.6
Age	16-20	59.3	64.7
	21-25	39.0	22.6
	26-30	1.0	11.3
	Above 30	0.5	1.5

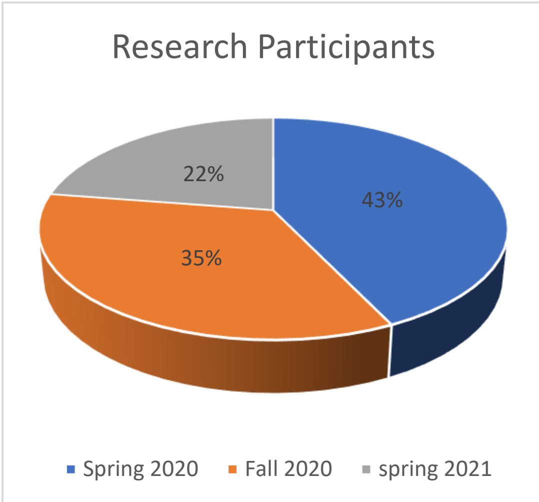


Figure 4.1 Percentage distribution of research participant for each semester

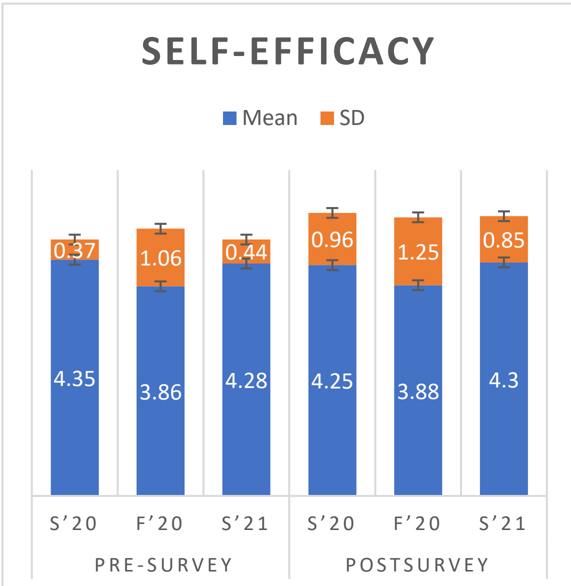
5. Results and Discussion

The data in Table 5.1 conveys the average self-efficacy (SE) and perceived value (PV) for pre- and post- surveys of each semester while Fig 5.1 (a) and Fig 5.1 (b) depict the graphical illustration of the trend in the mean and standard deviation of the SE and PV of environmental and biological engineering students for Spring 2020, Fall 2020 and Spring 2021. Table 5.2 and Fig. 5.2 depict the change in the Mean and Standard Deviation of SE and PV for the combined Pre and Post Surveys respectively.

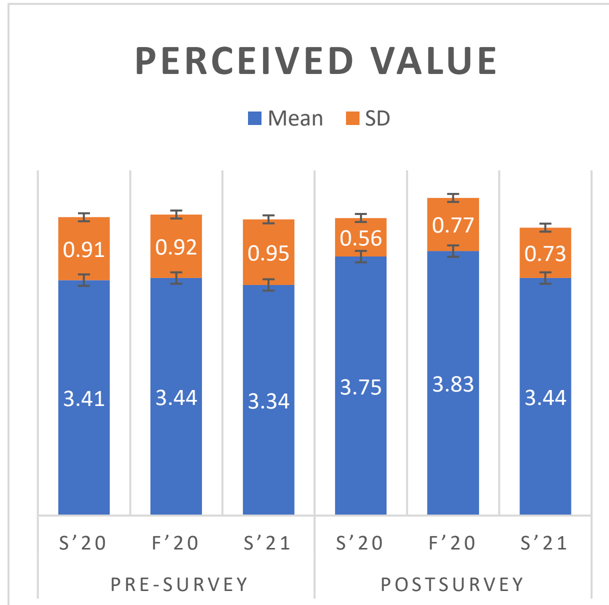
Table. 5.1 Trend in the means of the SE and PV of environmental and biological engineering students for the 3 semesters

		SELF-EFFICACY						PERCEIVED VALUE					
Major		PRE-SURVEY			POSTSURVEY			PRE-SURVEY			POST-SURVEY		
		S'20	F'20	S'21	S'20	F'20	S'21	S'20	F'20	S'21	S'20	F'20	S'21
Environmental and Biological Engr.	**Mean**	4.35	3.86	4.28	4.25	3.88	4.30	3.41	3.44	3.34	3.75	3.83	3.44
	SD	0.37	1.06	0.44	0.96	1.25	0.85	0.91	0.92	0.95	0.56	0.77	0.73

SPRING 2020 FALL 2020 SPRING 2021



(a)



(b)

Fig 5.1 Graphical illustration of the Trend in the SE and PV of environmental and biological engineering students for Spring 2020, Fall 2020 and Spring 2021

Table. 5.2 Trend in the means of the SE and PV of all students for the 3 semesters

		SELF-EFFICACY						PERCEIVED VALUE					
Major		PRE-SURVEY			POSTSURVEY			PRE-SURVEY			POST-SURVEY		
		S'20	F'20	S'21	S'20	F'20	S'21	S'20	F'20	S'21	S'20	F'20	S'21
Environmental and Biological Engr.	**Mean**	**4.35**	**3.86**	**4.28**	**4.25**	**3.88**	**4.30**	**3.41**	**3.44**	**3.34**	**3.75**	**3.83**	**3.44**
	SD	**0.37**	**1.06**	**0.44**	**0.96**	**1.25**	**0.85**	**0.91**	**0.92**	**0.95**	**0.56**	**0.77**	**0.73**
Mechanical Engr and Others	**Mean**	**4.28**	**4.18**	**4.53**	**4.25**	**4.36**	**4.50**	**4.23**	**4.17**	**4.65**	**4.26**	**4.41**	**4.36**
	SD	**0.65**	**0.80**	**0.48**	**0.83**	**0.79**	**0.78**	**0.61**	**0.46**	**0.43**	**0.78**	**0.47**	**0.83**
Total	**Mean**	**4.29**	**4.12**	**4.48**	**4.25**	**4.27**	**4.46**	**4.16**	**4.04**	**4.39**	**4.22**	**4.31**	**4.17**
	SD	**0.63**	**0.85**	**0.48**	**0.83**	**0.89**	**0.78**	**0.68**	**0.63**	**0.76**	**0.78**	**0.57**	**0.88**

SPRING 2020 FALL 2020 SPRING 2021

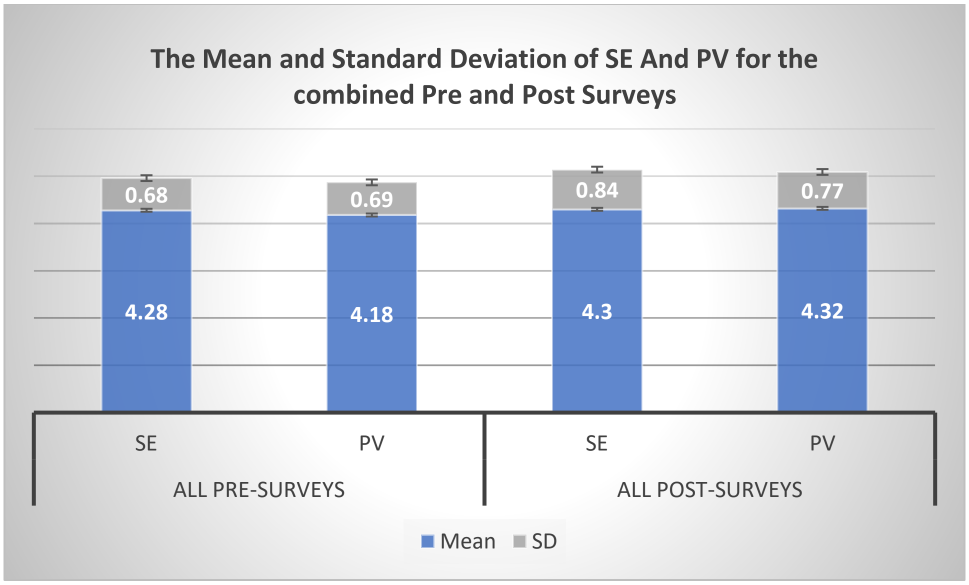


Fig. 5.2. The change in the Mean and Standard Deviation of SE and PV for the combine Pre and Post Surveys

In Spring 2020, the mean values for biological and environmental engineering students' SE decreased from 4.35±0.37 to 4.25±0.96 (resulting in a positive difference of 0.10) and the student's PV of the problems increased from 3.41±0.91 to 3.75±0.56 (with a positive difference of 0.34). For the Fall of 2020, the mean values of SE increased from 3.86±1.06 to 3.88±1.25 (resulting in a positive difference of 0.02) while that of the PV of the problems also saw an increase from 3.44±0.92 to 3.79±0.77 (with a positive difference of 0.35). Lastly, in the Spring of 2021, the mean values of SE increased from 4.28±0.44 to 4.30±0.85 (making a positive difference of 0.02), while the mean values of the PV of the problems for this last semester saw a first-time decrease from 3.34±0.96 to 3.31±0.77 (a negative difference of 0.03). In addition to this, there was an improvement in the biological and environmental engineering students' PV of the course with an increase of 0.22 for the combined pre (3.40±0.89) and post (3.62±0.73) surveys while the combined pre (4.14±0.74) and post (4.10±1.03) surveys showed that their self-efficacy did not portray much difference after the new problems were implemented.

Overall, the trends in the means of the three semesters' data and the change in the mean of the combined pre and post data revealed that the students' PV of the introduced problems increased, but their total SE did not elicit much difference. This indicates that the students appreciated the problems and found them worthwhile, but the problems did not make a significant impact on their self-efficacy throughout the semesters. However, the problems did seem to be a welcome and satisfactory addition to the course.

Wilcoxon signed ranked tests

In order to verify the significance of the collected data and its implications, Wilcoxon signed ranked tests were conducted using the found SE and PV for each semester's pre- and post-surveys. The test was run for each semester and then another test for the total conjoined data. Table 5.3 and Table 5.4 show the result of the Wilcoxon signed rank tests for the cojoined data.

Table 5.3 Wilcoxon Procedure's Ranks Table

Ranks				
		N	Mean Rank	Sum of Ranks
SE_Post – SE_Pre	Negative Ranks	49[a]	62.23	3049.50
	Positive Ranks	**71[b]**	**59.30**	**4210.50**
	Ties	13[c]		
	Total	133		
PV_Post – PV_Pre	Negative Ranks	43[d]	56.33	2366.00
	Positive Ranks	**76[e]**	**61.25**	**4655.00**
	Ties	14[f]		
	Total	133		

a. SE_Post < SE_Pre
b. SE_Post > SE_Pre
c. SE_Post = SE_Pre
d. PV_Post < PV_Pre
e. PV_Post > PV_Pre
f. PV_Post = PV_Pre

Out of the overall 133 participants in the study, there was an improvement in the SE of 71 participants after the implementation of the new problems, 13 participants saw no change in their SE of the course, and 49 participants seemed to find the new problems a bit challenging. Also, out of the 133 participants, 76 participants elicited an improvement in their PV of the problems to the course, 14 participants felt that the introduction of the new problems did not have effect on the perspective of the course, and 43 participants disapproved of the problems.

Table 5.4 Wilcoxon Signed Rank Test Statistics

Test Statistics[a]

	SE_Post – SE_Pre	PV_Post – PV_Pre
Z	-1.524[b]	-2.933[b]
Asymp. Sig. (2-tailed)	.128	.003

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

In summary, the result of the Wilcoxon Signed rank statistics showed that the PV of the students elicited a statistically significant median increase after the new problems were introduced to the course, $z = -2.93$, $p < .005$ while there was no statistically significant median increase in the SE of the participants after the problems were introduced to the course, $z = -1.52$, $p= 0.128$. This result proved to be consistent with the previous analysis. As for trends in biological and environmental engineering majors, the perceived value trended upwards for Spring 2020 and Fall 2020 while self-efficacy trended upwards for Fall 2020 and Spring 2021. The results show a general positive impact from the new problems; however, more data must be collected to draw definitive conclusions about the impact these problems might have on biological and environmental engineering students.

6. Limitations

One impactful event that occurred during data collection was the lockdown caused by the SARS-COVID-2 virus. These lockdowns had a tremendous effect on teaching, moving the class to an online style. While the data collected is still very useful, the lockdowns and the resulting remote experience may have had an impact on the students' answers to the survey questions. Another limitation of the study was the small percentage of biological and environmental engineering majors enrolled during the time of data collection. Because of this limitation, we do not have the statistical power to fully discuss the impact that the introduced problems on the biological and environmental engineering students. This was why this study looked into the trend in the means and incorporated the Wilcoxon signed-rank nonparametric procedure across students from all disciplines that took the course and decided to participate in the survey. Both limitations can be mitigated with further data collection. As such, this study is a work in progress.

Next Step

After all the data was collected for the Spring 2021 semester, a set of open-ended qualitative questions were developed to be asked in a semi-structured interview. The questions will provide a deeper understanding of quantitative results when students are able to contextualize their answers to the previous survey. One set of questions will attempt to answer, "What are the reasons provided by students, with regards to a change in self-efficacy, reflective of the implementation of environmental and biological engineering problems in a statics course?". Another set of questions will attempt to answer, "How does the composition of study groups within Statics impact self-efficacy of students engaged in solving homework problems?".

Also, more data would be collected in future semesters to reach a conclusion about the impact of these problems solely on biological and environmental engineering majors. This is because the result of the Wilcoxon signed-rank test from this study was combined from students across all engineering majors taking the class.

7. Conclusion

This research was developed to discover whether an impact could be made to biological and environmental engineering students' self-efficacy in statics if new problems were introduced that were more closely related to their field of study. Once these problems were created, they were introduced to students over the course of three semesters with little to no change in their distribution. Then, for extra credit, the students took surveys answering questions from which their answers could be used to calculate how the problems were received (Perceived Value), and how they influenced the students' own confidence in the class (Self-efficacy). Based on all the obtained survey responses, we were able to conclude that, although the majority felt that the introduced problems were worthwhile, the students' Self-efficacy did not significantly change by the introduction of these problems. However, it can also be concluded that the newly introduced problems did not negatively impact the self-efficacy of the students as a positive trend was found in the Descriptives of the students in terms of their self-efficacy even though it was statistically insignificant.

This research was, however, limited by the school's population of students enrolled in biological and environmental engineering majors. Also, there could have been influence from the COVID-19 pandemic that forced schools into online learning during the span of this research. Going forward, this research will be continued for the benefit of the targeted majors. However, moving forward with this research, a larger population of these students must be examined by adding additional semesters of data. It is recommended that additional universities be targeted to increase the number of biological and environmental engineering students from which data can be examined. This would also allow for a larger variety of discipline-specific problems to be developed for the study and to truly measure the targeted majors' Self-efficacy and meet their needs accordingly.

References

[1] H. Alves, "Perceived value index in higher education," *Innovative Marketing,* vol. 6, no. 2, pp.14-26, 2010.

[2] A. Ahmad & T. Safaria, "Effects of self-efficacy on students' academic performance," *Journal of Educational, Health and Community Psychology*, vol. 2, no.1, pp. 22-29, 2013.

[3] R. Atadero, M Balgopal, K. Rambo-Hernandez, & A.M. Casper, "Project-based Learning in Statics: Curriculum, Student Outcomes, and Ongoing Questions.," in *2014 ASEE Annual Conference & Exposition*, June 2014, pp. 24-1017.doi:10.18260/1-2—22950

[4] S.E. Bamforth, C.L. Robinson, T. Croft, T., & A. Crawford, "Retention and progression of engineering students with diverse mathematical backgrounds," *Teaching Mathematics and Its Applications: International Journal of the IMA*, vol. 26, no. 4, 156-166, 2007.

[5] M. K. Brown, C. Hershock, C.J. Finelli, & C. O'Neal, "Teaching for retention in science, engineering, and math disciplines: A guide for faculty," Occasional *paper*, vol. 25, pp. 1-12, 2009.

[6] G. Crosling, L. Thomas & M. Heagney, "Improving Student Retention in Higher Education," *Australian Universities' Review,* vol. 51., 2008. doi:10.4324/9780203935453

[7] A. Dollár, and P. Steif, "Reinventing the teaching of statics," in *2004 Annual Conference Proceedings*., June 2004, pp. 9-10, doi:10.18260/1-2—13940

[8] J. Engelbrecht, A. Harding, & J. Du Preez, "Long-term retention of basic mathematical knowledge and skills with engineering students," *European Journal of Engineering Education*, vol. 32, no. 6, pp.735-744, 2007.

[9] Halimatussakdiah, M.S.A. Majid, & N. Azis, "Mediating effect of student perceived value on student satisfaction in the Indonesian private higher education institutions," *International Journal of Management in Education*, vol.14, no. 6, pp. 611-627, 2020.

[10] L. Kaddam, and M.K.M. Elnimeiri, "Students' perceived value of physiology course activities in a Sudanese medical faculty," Advances *in Physiology Education*, vol. 36, no.4, pp.298-301, 2012.

[11] S.J. Krause, J.A. Middleton, E. Judson, J. Ernzen,, K.R. Beeley & Y.C. Chen, "Factors impacting retention and success of undergraduate engineering students," in *2015 ASEE Annual Conference & Exposition*, June 2015, pp. 26-758.

[12] L. Ledden, S.P. Kalafatis, & P. Samouel, "The relationship between personal values and perceived value of education," *Journal of Business Research,* vol. 60, no. 9, pp.965-974, 2007, doi: 10.1016/j.jbusres.2007.01.021.

[13] R. W. Lent, S.D. Brown, & G. Hackett, "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance," *Journal of Vocational Behavior,* vol. 45, no.1, pp.79-122, 1994, doi:10.1006/jvbe.1994.1027

[14] D. McAvoy, "A repeated exposure experiment to improve knowledge retention," in *2010 Annual Conference & Exposition*, June 2010, pp. 15-81.

[15] M. Meral, E. Colak & E. Zereyak, "The relationship between self-efficacy and academic Performance," *Procedia-Social and Behavioral Sciences*, vol. 46, pp.1143-1146.

[16] T. Lai Mooi, "Self-efficacy and student performance in an accounting course," *Journal of Financial Reporting and Accounting*, vol. 14, no 1, pp.129-146, 2006.

[17] R.L. Navarro, L.Y. Flores, J. Legerski, J. Brionez, S.F. May, H.N. Suh, . . ., A. Jung "Social cognitive predictors of engineering students' academic persistence intentions, satisfaction, and engagement," *Journal of Counseling Psychology,* vol. 66, no. 2, pp.170-183, 2019, doi:10.1037/cou0000319.

[18] D. Oerther, “Integrating Biological Principles in Environmental Engineering: Summary Results Of A Three-Year Pilot Study,” in *2003 ASEE Annual Conference Proceedings*, June 2003, pp.8-721, doi:10.18260/1-2—12315.

[19] J. Serrano-Mira, J.V. Abellan-Nebot & G.M. Bruscas-Bellido, “Knowledge Retention of Manufacturing Concepts in Short and Medium Term in Engineering Degrees,” in *Key Engineering Materials*, vol. 615, pp. 183-188, 2014.

[20] H. Steenkamp, A.L. Nel, & J. Carroll, “Retention of engineering students,” in *2017 IEEE Global Engineering Education Conference (EDUCON)*, April 2017, pp. 693-698.

[21] S. J. Hillman, “Measuring Self-Efficacy: Preliminary Steps in the Development of a Multi-Dimensional Instrument,” in *Annual Meeting of the American Educational Research Association*, April 1986, pp.1-50.

[22] Y.A. Unrau and A.R. Beck, “Increasing research self-efficacy among students in professional academic programs’” *Innovative higher education*, vol. 28, no. 3, pp.187-204, 2004.

[23] T. Yildirim, M. Besterfield-Sacre & L. Shuman, “*Scale Development For Engineering Modeling Self Efficacy* ,” *2010 Annual Conference & Exposition Proceedings*., June 2010, pp. 15.1050.1 - 15.1050.20, doi:10.18260/1-2—16033.

[24] V.A. Zeithaml, “Consumer Perceptions of Price, Quality, and Value: A Means-End Model and Synthesis of Evidence,” *Journal of Marketing,* vol. 52, no. 3, pp.2-22, 1988.

[25] B.J. Zimmerman, “Self-efficacy: An essential motive to learn,” *Contemporary educational psychology*, vol. 25, no. 1, pp.82-91, 2000.

Appendix I

Newly Developed Biological and Environmental Engineering Themed Problems

Four new homework problems were developed in the topic areas of:

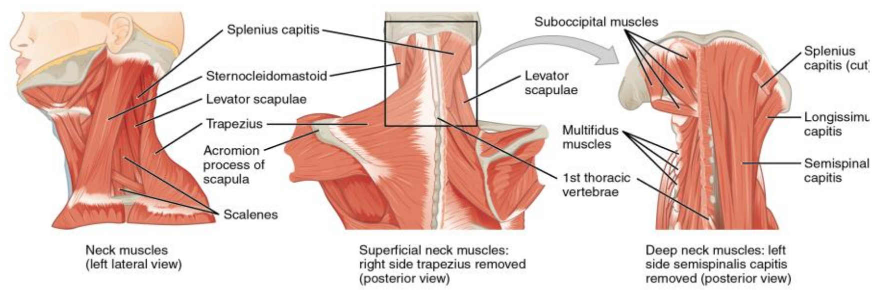
- Forces and Moments on Cervical Vertebrae (Biological Engr.)
- Green Roof Truss (Environmental Engr)
- Digital Pulley in Rock Climbing (Biological Engr.)
- Reverse Osmosis (Environmental Engr)

Two of the problems are shown below:

Forces and Moments on Cervical Vertebrae

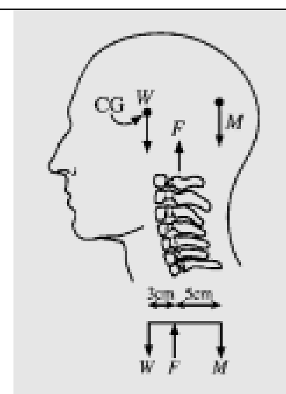
Introduction

The muscles in the neck that extend the neck and hold up the head include the semispinalis capitis, the splenius capitis, and the longissimus capitis. These muscles are located on the back of the neck.



Problem: The extensor muscles exert a force (M) to hold up the head. The weight of the head (W) acts at the center of gravity (CG). The first cervical vertebra exerts a force (F). Using the dimensions in the figure on the right and assuming the head has a weight of 50 N: ($1\ N/m^2 = 1\ Pa$)

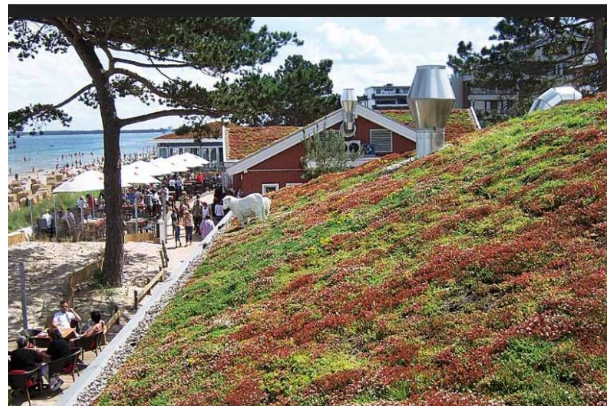
a) Find the forces F and M in Newtons;
b) Find the stress (in kPa) on the first cervical vertebra assuming it has an area of $5 \times 10^{-4}\ m^2$;
c) The average rupture compression strength of the intervertebral discs is 11,000 kPa. Will the stress from part b) cause the disc to rupture?



Green Roof Problem

Introduction

The most basic definition of a Green Roof is a roof that has live, growing plants. In order to accomplish this, the roof must have a layer of water-proofing, a system to protect the roof structure from roots, a drainage system, filters, and soil. All of this, in addition to the water necessary to grow the plants, adds weight which needs to be accounted for when considering the roof trusses.



Problem: The specific weight of the green roof system (including the soil, water, plants, etc.) is 96 lb/ft^3. Based on common roof dimensions, this results in a distributed load (W) of 71 lb/ft on each side as shown in the symmetrical figure on the right. This load acts on members AD and DI, which are 10 ft long. If the angle of the roof pitch θ = 45°, find the forces in member BC and member CE using the Method of Joints. Also determine if the forces act in tension or compression.

Hint: You need to convert the distributed load to point loads acting on the joints.