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Measuring Engineering Students' Engagement in Sustainability Design Concepts

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Measuring Engineering Students' Engagement in Sustainability Design Concepts

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Donald Plumlee (Associate Dean)

Measuring Engineering Students' Gender Based Issues in Sustainability Design Concepts

Abstract

There has been a push to incorporate sustainability concepts into engineering education within industries, governments, and accreditation organizations. Universities like Boise State University (BSU) are starting to place greater emphasis on the inclusion of sustainability concepts in different engineering program curricula. As part of a project funded by the National Science Foundation (NSF), the BSU mechanical engineering program integrates sustainability concepts specifically by using active learning modules (ALMs) suitable for each student's education level, progressing from freshman to senior. ALMs have shown to be more effective in improving motivation in the classroom compared to traditional learning. A modified survey instrument was developed for distribution to BSU mechanical engineering, engineering plus students, and alumni; both the student and alumni survey was modified using the 2009 American Society of Mechanical Engineerings' (ASME) sustainability survey with a combination of a study by Natasha Lanziner. Current mechanical engineering and engineering plus students were surveyed to gauge their knowledge and attitudes toward sustainability in the curriculum. Mechanical engineering alumni were surveyed to determine which sustainability practices are utilized in their workplaces. By applying a quantitative approach to the survey instrument, Boise State Engineering students and alumni will have the opportunity to express their perception of BSU's current integration of sustainability concepts. The data presents common sustainability trends based on the gender demographics of both students and alumni data. Specifically, the student data illustrates their general thoughts regarding ALMs and sustainability; most students, especially women, showed interest in sustainability when exposed to BSU alumni applying sustainability to their design work. As a general trend based on the alumni data, women also tended to feel less confident in applying sustainability to their design work. However, they were more interested in the concept than men. This paper will suggest improvements in ALMs related to sustainability concepts at Boise State University.

Introduction

In recent years, sustainability concepts have piqued an interest in many professional communities and have been emphasized in workforce development and student education [1], [2]. With interest in sustainability rising, many universities have begun integrating sustainability concepts into their engineering curriculum [3]–[5]. Many universities, including Boise State University (BSU), introduced sustainable concepts with active learning modules (ALMs) to introductory courses, particularly among first-year and second-year engineering college students. The traditional method of teaching has historically relied on lecturing. While this method has been proven to be reasonably effective in passing on knowledge, studies have shown that students are less likely to be fully engaged. Student activity during lectures is limited, and as a result, the learning is passive due to factors such as instructor time constraints and notetaking. ALMs are defined as strategies that actively present engaging activities such as discussions in class, case studies, and presentations, aiming to restructure the traditional passive teaching format. A recent meta-study across STEM disciplines has determined that using active learning techniques in place of lectures can reduce course failure by 1.5 times the average rate; these

techniques also benefit increasing student learning compared to traditional lecturing [6]. The results also show that test scores improved by 6% with active learning sections [6]. Although 6% is not statistically higher, participating in active learning sections can increase engagement with the presented modules and material.

The Mechanical and Biomedical Engineering Department has recently modernized the BS in Mechanical Engineering curriculum. The primary goals of the new program are to develop more experiential learning opportunities, allow more flexibility with course selection, and create focused, themed learning tracks in the curriculum [7]. The program's modernization provides a significant opportunity to embed relevant concepts of sustainability into the curriculum by aligning them with the themed learning tracks. Students can better recall these concepts by consistently and logically introducing sustainability concepts throughout the curriculum. Likewise, through the repetition of sustainability concepts, students will also be able to understand the concepts and apply them to their design work. It was stated that the new, modernized program would create sustainability content using engineering examples to assist student comprehension throughout the curriculum. BSU's new improved undergraduate curriculum will allow BSU to be well-positioned to adopt highly relevant sustainability course content. This study will measure first-year and second-year students' engagement in sustainability concepts and improve the ALMs to match the improved curriculum.

Literature Review

Sustainability Integration Background

Introducing sustainability concepts into the existing engineering programs can be grouped into two approaches: horizontal and vertical integration [3]–[5], [8]. Vertical integration introduces new sustainability courses in engineering curricula, which can be offered as electives [3]–[5], [8]. The vertical approach does not require significant training for instructional faculty across the curriculum, as the integration is often focused on a separate course in the curriculum [8]. In contrast, horizontal integration includes the addition of sustainability concepts into multiple existing courses [3], [5], [8]. The horizontal approach revises existing courses to include environmental and social issues topics that teaches students about tradeoffs that exist while using the triple bottom line [5]. However, there are some disadvantages of using the horizontal method, including limited instructor awareness of sustainability concepts in a specific discipline, instructors misunderstanding the meaning of sustainability concepts, and instructors simply not viewing sustainability as an essential concept to teach [8]. Despite its challenges, the horizontal method is preferable to the vertical method; in the horizontal method, students are introduced to a concept multiple times in a progressive structure that improves learning and retention. The horizontal approach ultimately helps students and instructors learn about sustainability concepts and their application in academic and professional settings.

In the pursuit of integrating these concepts into their curricula, special undergraduate programs in other universities have attempted to implement the horizontal method into their approach, which has posed its challenges. At Michigan Tech, an established program called Sustainable Futures Institute (SFI) focuses on research and education to provide solutions to sustainability

challenges [9]. To help in this endeavor, the SFI has emphasized sustainability in graduate and undergraduate curricula [9]. The modules designed by Michigan Tech created awareness among mechanical engineering students. However, experts from Michigan Tech suggested that to increase engagement in sustainability, the curricula should provide students with more real-world learning experiences [9].

Similarly, BSU introduced sustainability in the civil engineering curriculum by adding a course specifically dedicated to sustainability; this solved the lack of S&R coverage and modified the existing traditional teaching method [10]. Interviews were conducted with senior civil engineering students to understand attitudes toward S&R concepts better. The interview questions were based on students' knowledge by describing their understanding of S&R concepts from the civil engineering courses [10]. A common theme found in the study was that students could describe what they learned from their participation in the course. Some even related their senior design project and internship experience to S&R concepts. Most students were able to describe attributes of S&R concepts related to prior experiences, such as internships and their roles in their senior design projects [10]. As part of this project, this success in the civil engineering curriculum is being incorporated into the other engineering disciplines at BSU by introducing ALMs.

Women and Sustainability

BSU has seen an increase in female enrollment, specifically those majoring in mechanical engineering. In the academic year 2020-2021, about 38% of women enrolled in STEM-related fields, creating a 10% increase since 2016-2017 [11]. Women's involvement in STEM has reduced gender-role stereotypes and has brought a different perspective to the classroom. Even with the assets women bring to the classroom, women often lack self-confidence, academic efficacy, and a sense of belonging, undermining their commitment to continue their field of study [12]. Despite these stereotypes, women statistically receive a higher course grade than men and are likely to outperform men in science courses [13]. A study found that collaborative learning and hands-on experimentation have increased girls' confidence and interest in the STEM field [14], [15]. Adding ALMs to BSU's engineering curriculum can further enhance women's confidence levels in STEM.

The stereotypes found between women's confidence levels and sustainability are linked to the theory of ecofeminism. Ecofeminism emphasizes the need to understand women's and men's relationship with nature as rooted in their material reality and how gender- and class-based interactions with nature structure knowledge about nature, the effects of environmental change, and responses to it [16]. Ecofeminism has crept into many women's professional lives, particularly in sustainability. For example, in rural areas, it is commonly believed that women are known as caretakers and nurturers and, as such, have a closer relationship with nature. By virtue of women's biological relationship to reproduction, ecofeminists have linked women to have a connection with nature [16]. Understanding confidence concerns based on gender will help with understanding sustainability engagement presented in the ALMs. This paper will explore the difference in interest between current students and alumni.

Methods

Survey

To further understand students' engagement in sustainable practices, Lanziner developed a survey to explore this question [17]. The quantitative research study focused on undergraduate students enrolled in Canadian accredited programs [17]. Lanziner developed a survey instrument that included demographic questions, three open-ended questions, and 31 closed-ended questions that focused on stereotypes and previous experiences, self-concepts of abilities, and subjective task values. All closed-ended questions were structured as a 5-point Likert-scaled [17] which allows the participants to select a thoughtful answer rather than inputting a rubbish response. Lanziner's results show that most students were biased towards the environmental pillar in sustainable engineering practice regardless of background. It is recommended that students have a universal definition of all integrations of the triple bottom line and understand inherent tradeoffs when applying sustainability to their projects.

In late 2009, a survey conducted on engineers and engineering students indicated a strong focus on implementing sustainability concepts in education [18], [19]. The survey was sent out to ASME members to determine the attitudes of engineers towards sustainability, and the results suggested that many companies are adopting sustainability practices [18], [19]. This is just one of many instances of sustainability practices becoming more common in industry. Research has suggested that industries nationwide and across the globe are adopting more sustainable practices [19], instructors must bridge the gap between the academic and the professional world.

The surveys created for both BSU alumni and students are based on questions from the ASME annual sustainability survey and Lanier's survey. The questions related to the 2009 ASME survey were organized to understand a person’s involvement in sustainability, whereas Lanziner's survey allows to see the engagement behind sustainability. The student survey instrument includes 12 closed-ended questions and one open-ended question, and the alumni survey consists of 18 closed-ended questions. All closed-ended questions were structured as a 5-point Likert scale. There will be approximately 358 participants across both the student and alumni surveys.

Research Design

With the rise of sustainability within engineering, there has been an effort to understand the attitudes and behaviors regarding sustainability in practicing engineers [19]. Students who experienced the modified ALMs were asked to participate in a survey related to their knowledge and attitudes toward sustainability concepts. Figure 1 displays the research design for each semester. In Summer 2021, a survey was given to BSU mechanical engineering alumni to determine how sustainability is used in industries relevant to BSU students. After completing the ALMs in Spring 2021, students were asked to do a post-survey. The results found in Spring 2021 have been used as baseline data to understand students' knowledge and attitudes. Additionally, in Fall 2021 and Spring 2022, students have participated in newly developed ALMs and have an opportunity for their feedback to be used in new sustainability teaching methods. At the start of the semester, students enrolled in Fall 2021 and Spring 2022 have taken a pre-survey before being introduced to the ALMs, followed by a post-survey at the end of the semester.

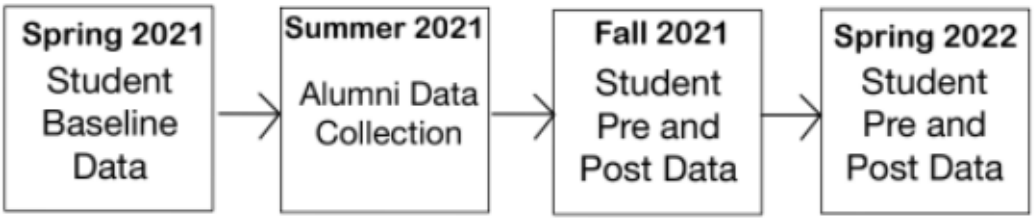

Figure 1. Research Design

The survey was distributed to Boise State mechanical engineering alumni and current students taking Design 1 (ME 287) and Communication in Design Thinking (ENGR 180). ME 287 is an introductory required course for all mechanical engineering students that focus on engineering design theory, design processes, and codes and standards. ENGR 180 is tailored to Engineering Plus students; this course focuses on analyzing human-centered and global challenges. Engineering Plus is an ABET-accredited degree that introduces different engineering principles by incorporating Boise State's College of Engineering courses (Mechanical, Civil, and Electrical Engineering, Material Science, and Computer Science), a student is then able to choose a concentration in one of the e+ pathways. While this study focuses primarily on mechanical engineering students, engineering plus students has been chosen to participate given the similarities in courses compared to mechanical engineering students. ME 287 and ENGR 180 teach practicing engineers about ethics and designs concepts, these courses are ideal for introducing sustainability concepts.

Sustainability was not the primary focus of these engineering introduction courses. However, given the limited time allotted for this concept, sustainability was introduced with ALMs that focused on in-class videos followed up with in-person discussion, alumni guest speakers, and walking tours. Table 1 describes the different methods utilized in the introductory engineering courses. The data found in this study indicates student engagement based on the ALM that was implemented in their course. Students were presented with different active learning activities that

caused them to receive different results per semester. These activities included using case studies, providing guest speakers, and further explaining sustainability modules.

Table 1. Sustainability Modules added

Module	Description	Semester
Alumni Guest Speaker	A BSU alumnus, who has worked with sustainability concepts, is invited into class as a guest speaker. Speaker elaborates on their experiences with sustainability in their workplace.	SPRING 2021
Sustainability Walking Tour with Boise State's Environmental Health, Safety and Sustainability Department	The Environmental Health, Safety, and Sustainability Department has created a virtual walking tour that discusses the sustainable practices BSU does around campus. Students are grouped to answer a questionnaire as an assignment.	FALL 2021
In-Class Discussions/Videos	The lecturer allows students to watch an in-class video. Students work in groups to follow up with an in-class discussion to identify the inherent sustainability tradeoffs that relate to the video.	SPRING/FALL 2021

Students Evaluations

Each sample size changes per semester based on the number of students registered in each tested course. Although it is not required for the students to participate in the survey, extra credit is offered to the students as an incentive to participate in the survey and gain a higher response rate. The student participants were selected by their enrollment in ME 180 and ME 287. The total population of students enrolled for all semesters in ME 287 and ENGR 180 was 282. The data from Spring 2021 was surveyed at a post-survey data collection. Students were not required to perform a pre-survey, unlike the students from Fall 2021/Spring 2022. The data from Spring 2021 will be used as baseline data to understand students' engagement with sustainability. For Spring 2021, in ME 287, there were 27 students enrolled in the course and 42 students in ENGR 180. The surveys received a high response rate of 53% and yielded a sample size of 69. Table 2 displays the gender demographics defined by Male, Female, and "Prefer not to say". 37 out of 69 students responded to the survey; 64.9% of responses were male, 29.7% were women, and 5.4% preferred not to say.

Table 2. Spring 2021 Demographics of BSU Students in ME 280 and ENGR 180 (N=37)

Independent Variable	Group	N	%
Gender	Male	24	64.9
	Female	11	29.7
	Prefer not to say	2	5.4

Unlike the dataset from Spring 2021, the students participating in these courses for Fall 2021 and Spring 2022 will have a pre-and post-survey better to identify the outcome of ALMs and sustainability. For Fall 2021, in ME 287, there were 59 students enrolled in the course. For ENGR 180, there were 46 students enrolled in the course. The response rate for the pre-survey for Fall 2021 was 81%, with a sample size of 105. Table 3 exhibits that 85 out of 105 students responded to the survey with a percentage of 76.5% male responses, 22.4% women, and 1.2% who responded with prefer not to say. Table 4 represents the 35 out of 105 who responded to the survey. The response rate for the post-survey in Fall 2021 was 33.3% which is less than the pre-survey response rate. Regardless of the lower response rate from the pre-survey, the percentage average of males, women, and prefer not to say are equivalent to the post-survey. The average percentage of male responses was 77.1%, 20% for women, and 2.9% in prefer not to say. The difference in average percentage from gender demographics in males was about 0.6%, 2.4% for women, and 1.7% for prefer not to say.

Table 3. Pre-Test Demographics of BSU Students in ME 280 and ENGR 180 (N=85)

Independent Variable	**Group**	**N**	**%**
Gender	Male	65	76.5
	Female	19	22.4
	Prefer not to say	1	1.2

Table 4. Post-Test Demographics of BSU Students in ME 280 and ENGR 180 (N=35)

Independent Variable	**Group**	**N**	**%**
Gender	Male	27	77.1
	Female	7	20.0
	Prefer not to say	1	2.9

For Spring 2022, there are 50 students in ME 287, and in ENGR 180, there are 8 students. The response rate and gender demographics for Spring 2022 are still to be determined. It is expected that there will be a similar response rate for gender demographics.

Alumni Evaluation

BSU's mechanical engineering alumni were also invited to participate in a separate survey specifically designed for alumni. A comprehensive list was obtained from the Mechanical and Biomedical Engineering department. The contact information included the alumni's email, first name, last name, LinkedIn/Facebook URLs, and graduation date. The alumni's graduation year spans from 2000 until 2020. 1091 participants were invited to participate in the survey, with 126 responses, creating a response rate of 11.5%. Table 5 shows the gender demographics results of participants that responded. According to Table 5, the response rates are 80.2% male, 15.9% female, and 4% prefer not to say. BSU has been on a mission to promote diversity equity, specifically in gender and racial inequality. The number of women obtaining engineering roles has risen, as seen in Tables 2, 3, and 4.

Table 5: Demographics of BSU Alumni in Survey – total 126

Independent Variable	Group	N	%
Gender	Male	101	80.2
	Female	20	15.9
	Prefer not to say	5	4.0

Data Analysis and Results

The Institute for Inclusive & Transformative Scholarship (IFITS) at BSU conducted a study to determine the percentage of demographics enrolled in STEM majors from Fall 2017-2021 [11]. At the graduate level, by each year, the population of women is increasing, while the percentage of male enrollments is decreasing. BSU engineering students are predominately male at the undergraduate level, composing an average of 66% of total enrollment. From Fall 2017–to 2021, female enrollment in STEM programs at BSU totaled an average of 34%. Figure 2 shows the percentage of gender demographics per fall semester. Given that there is an increase in female enrollment, the data for this study was an analysis based on gender demographics. These trends will determine students' engagement based on gender who experienced the new ALMs in their courses and BSU alumni who hold employment in their respective fields.

ACADEMIC CAREER	GENDER	Fall 2017	Fall 2018	Fall 2019	Fall 2020	Fall 2021
UNDERGRADUATE	**ALL GENDERS**	**100%**	**100%**	**100%**	**100%**	**100%**
Undergraduate	Female	32%	33%	35%	36%	34%
Undergraduate	Male	68%	67%	65%	64%	66%
Undergraduate	Unknown	0%	0%	0%	0%	0%
GRADUATE	**ALL GENDERS**	**100%**	**100%**	**100%**	**100%**	**100%**
Graduate	Female	34%	34%	37%	43%	41%
Graduate	Male	66%	66%	62%	57%	58%
Graduate	Unknown	0%	0%	0%	0%	0%

Figure 2. Boise State University STEM Gender Demographics from the Institute for Inclusive & Transformative Scholarship [11]

In the past, BSU and many other organizations have used Qualtrics XM to distribute surveys. Qualtrics XM has grown in popularity due to its efficiency and high capability of designing, sending, and analyzing surveys. Due to its popularity, Qualtrics XM was deemed suitable to distribute the survey to both the students and alumni participants. The alumni and student surveys were issued electronically with multiple reminders throughout the semester via email. Python was used for the quantitative data analysis to statistically identify the output in demographics in both the alumni and student survey. The trends found in python will evaluate

students' knowledge and attitudes based on those who were introduced to the modified ALMs and those whose responses served as the baseline data. The themes found in each semester and alumni results will influence the change in engagement and the teaching of sustainability. Rather than having select data overshadowed by the whole average of all students, each data was divided by their group to better understand the trends found from each demographic individually.

Student Data Analysis

Students in Spring 2021 had the opportunity to have a guest speaker talk about their experiences in the work field and their involvement with sustainability; the guest speaker in Spring 2021 was a BSU alum who had previously worked with commercial-grade refrigeration. Figures 3, 4, and 5 represent the students' responses to the question of *"Outside of work, how interested are you personally in green and sustainability information and causes"* for Spring 2021 and Fall 2021. The horizontal axis represents a 5-point Likert scale of which participants rate which they agree or disagree from Extremely Interested to Not Interested. The vertical axis represents the percentage of response. Figure 3 displays the results from the post-survey from Spring 2021, which showed that the students were highly engaged in learning about the different applications of sustainability from real-life examples. Note that females in this cohort were more engaged than males. About 38% of women were extremely interested in sustainability information and causes, while only 20% were extremely interested. Another noteworthy observation was that about 75% of women responded as somewhat interested, while 60% of men responded similarly, totaling a 15% disparity in engagement level. It is worth mentioning that the guest speaker was female, which raises the possibility that this affected the female responses more than the men's responses. Based on previous observations on ecofeminism and current cultural hurdles that women in the workforce face, having a female guest speaker reinforces relatability and encouragement to female students.

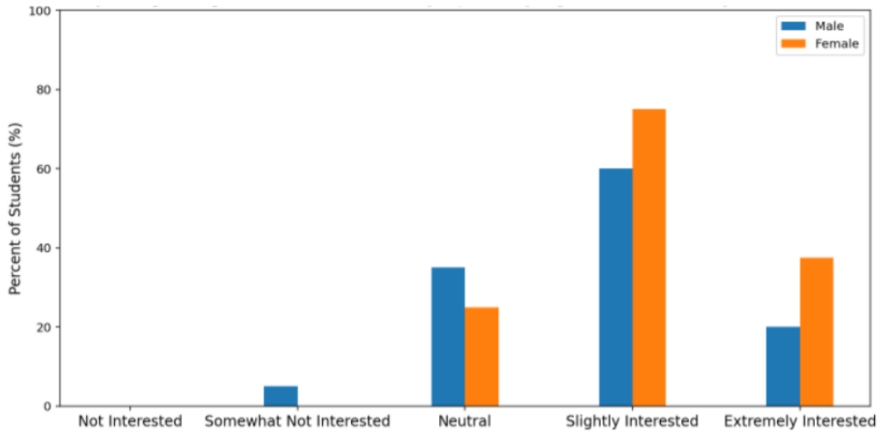

Figure 3. *Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes" for Spring 2021*

Figures 4 and 5 address the data from the pre-and post-survey in the combination courses of ENGR 180 and ME 287. In Fall 2021, the students' ALMs differed from Spring 2021. Unlike the students from Spring 2021, this cohort participated in a tour with Boise State's Environmental Health, Safety, and Sustainability Department rather than a guest lecturer. The lecture presented allowed students to see the impact BSU is creating with its sustainable engineering applications. Students had more in-class discussions about basic renewable energy systems, apart from the walking tour. Regardless of the change in ALMs, the results were similar to the results from Spring 2021 (Figure 5): Females became more personally interested in sustainability than men. Based on the post-survey, about 33% of females were more interested in sustainability than men. There was a drop in interest from the pre-and post-survey. In the pre-survey, 44.4% of women were highly interested in sustainability information and causes. Although there was a 10% drop in interest, this could have been due to the drastic response rate from the pre-and post-survey.

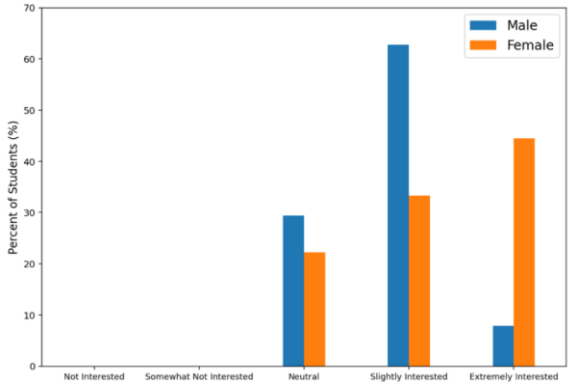

Figure 4. *Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes" for Fall 2021-Pre Survey*

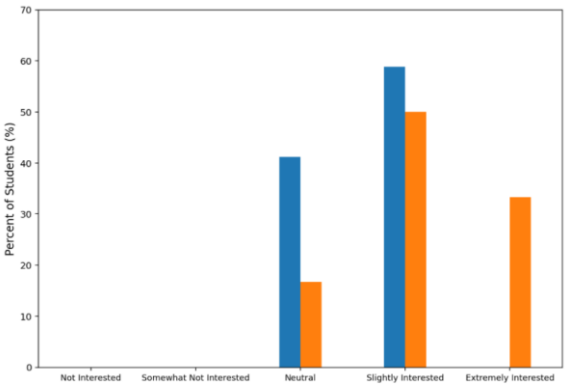

Figure 5. *Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes" for Fall 2021-Post Survey*

Regardless of the difference in the ALMs, each cohort was presented, students were able to understand the importance of sustainability. Figures 6, 7, and 8 display bar graphs that answer the question, *"To what extent do you agree or disagree with each of the following statements about the use of sustainable and/or green design principles in the design, production, and operation of manufactured products?"* From left to right, each bar represents a respective statement:

Q1: Designing sustainable and/or green products results more product innovation

Q2: The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems

Q3: Projects that follow sustainable and/or green design principles typically have higher design costs

Q4: Incorporating sustainable and/or green design practices is too complex for my educational institution

Each bar graph represents a different question that is then used as a 5-point Likert scale of which participants rate to which they agree or disagree. Based on Figure 6, students agreed that adding sustainable engineering practices can lead to innovative products, as shown in Q1. Based on the results from Q4, students strongly disagreed that incorporating sustainable and green design practices will not be complex for their educational institution (BSU). This verification can result in better and more thorough implementation of sustainability concepts in future curricula.

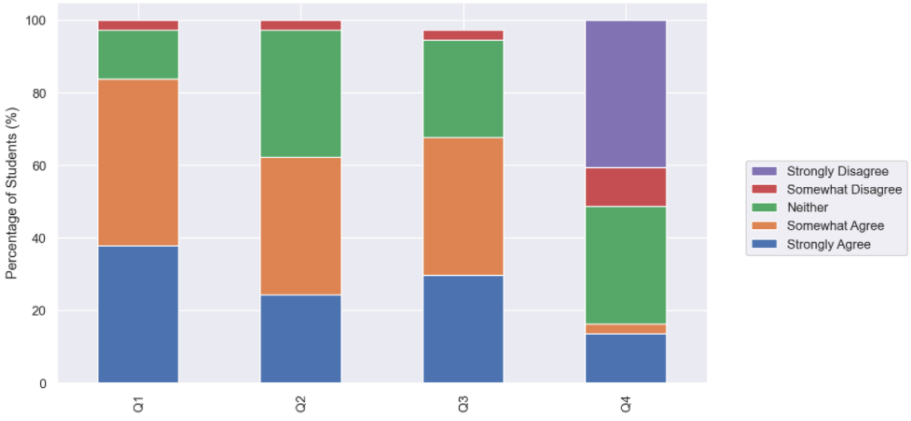

Figure 6. *Student results for Spring 2021*

Unlike Spring 2021, the pre-survey for Fall 2021 had different trends. In the pre-survey, most students agreed that projects that follow sustainable and/or green design principles typically have higher design costs. The ALMs changed their perspective, as seen in Figure 8, as the majority of the students agreed that sustainability projects result in innovation. For the post-survey, the cohort in Fall 2021 had similar trends as the cohort from Spring 2021. This cohort also had the belief that BSU could add sustainable and green practices to their university as seen in Q4.

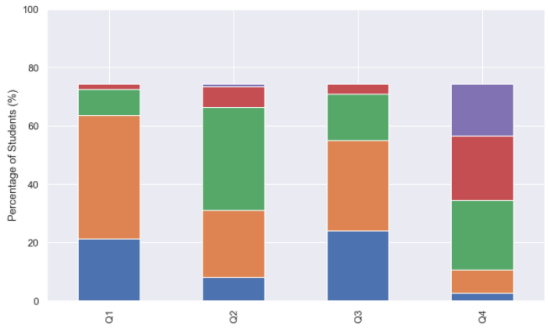

Figure 7. *Student results for question for Fall 2021-Pre Survey*

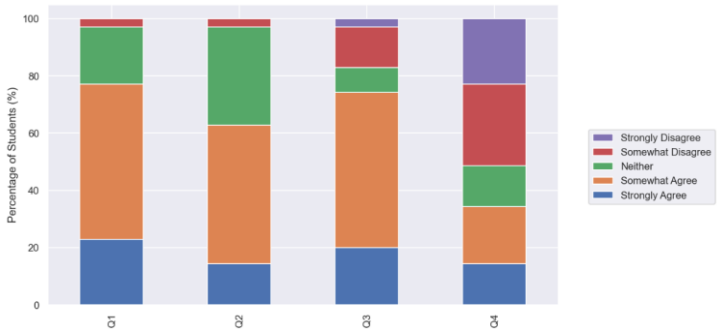

Figure 8. *Student results for question for Fall 2021-Post Survey*

Alumni Data Results

Alumni and the student participants had similar questions in their surveys. Figure 9 represents the data from the question of, *"Outside of work, how interested are you personally in green and sustainability information and causes".* The horizontal axis is a 5-point Likert scale of which participants rate to which they agree or disagree from Extremely Interested to Not at All Interested. In comparison to the student data, women were extremely interested in sustainability information and causes. Women tend to be "Extremely Interested" in sustainability concepts compared to men. About 58% of women are highly interested in sustainability information and causes. In comparison, only men are about 37% extremely interested, which is a notably higher average than the student data from Figures 3, 4, and 5. The alumni's interest in sustainability information and causes can be from their individual experience working in industry. The difference in sustainable engineering practices each company adds into their work environment differs from company to company. As a result, companies have been adding sustainable practices to increase efficiency, meet consumer demands, and add brand value to their company.

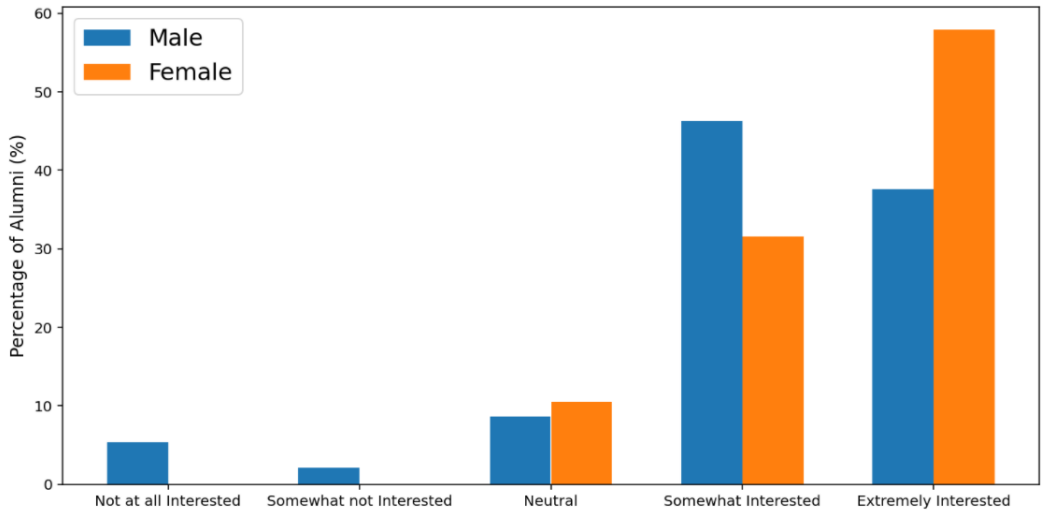

Figure 9. *Alumni results for the question "Outside of work, how interested are you personally in green and sustainability information and causes?"*

Before working in industry, some alumni recalled feeling a lack of confidence in applying sustainability into their design work. Figure 10 represents the alumni's response to the survey question of *"Before working in industry, how confident were you in ability to apply sustainability into your design?".* The horizontal axis represents a 5-point Likert scale of Extremely Confident, Very Confident, Moderately Confident, Somewhat Confident. The vertical axis represents the percentage of response. Before entering the work field, the confidence levels show different trends for each gender based on the graph. The percentage of men tends to be moderately confident or somewhat confident with applying sustainability into their designs. 50% of women reported being not confident in applying sustainability, and only 12% of women reported being very confident. Because the alumni participants had little to no coverage of sustainability concepts during their undergraduate career, it's assumed that this directly affected

their confidence levels in applying sustainable practices in their work. As shown in Figure 10, it is possible to influence confidence levels and one's ability to add sustainability into their design work.

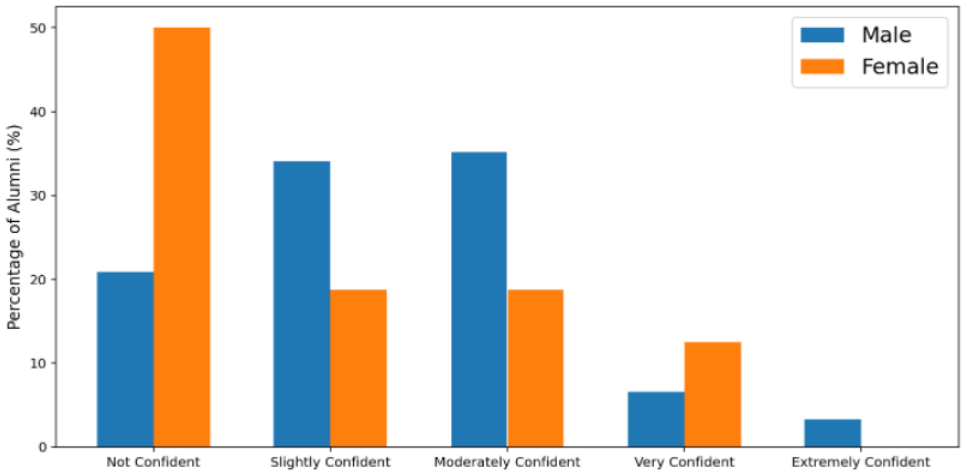

Figure 10. *Alumni results for the question "Before working in industry, how confident were you in ability to apply sustainability into your design?"*

To further understand the perspective of alumni participants in sustainability applications, they responded to a series of 5-point Likert scales to 8 questions. Figure 11 shows the alumni's response to "*Which of the following sustainable technologies do you consider to be the most important?".* From left to right, each bar represents a respective statement:

Q1: Designs that use less energy or reduce emissions

Q2: Designs that comply with Environmental Standards and Regulations

Q3: Designs that use renewable/recyclable/recycled materials

Q4: Designs that reduce material waste in manufacturing

Q5: Manufacturing processes that use less energy and natural resources

Q6: Manufacturing processes that produce less pollution and greenhouse gases

Q7: Products that can be disposed of safely, including biodegradable materials and packaging

Q8: Products that require less packaging

Q9: Other

The horizontal axis represents the statement they answer with a Likert scale ranging from Extremely Important, Very Important, Moderately Important, Slightly Not Important, or Not at All Important. The vertical axis represents the percentage of responses based on each Likert category. About 41% of the group agreed that designs that comply with environmental standards and regulations are essential when working in industry. About 38% agreed that designs that use less energy or reduce emissions are the second most important topic that is often used in their design work. In contrast, most agreed that recyclable materials in products and packaging were lower priorities.

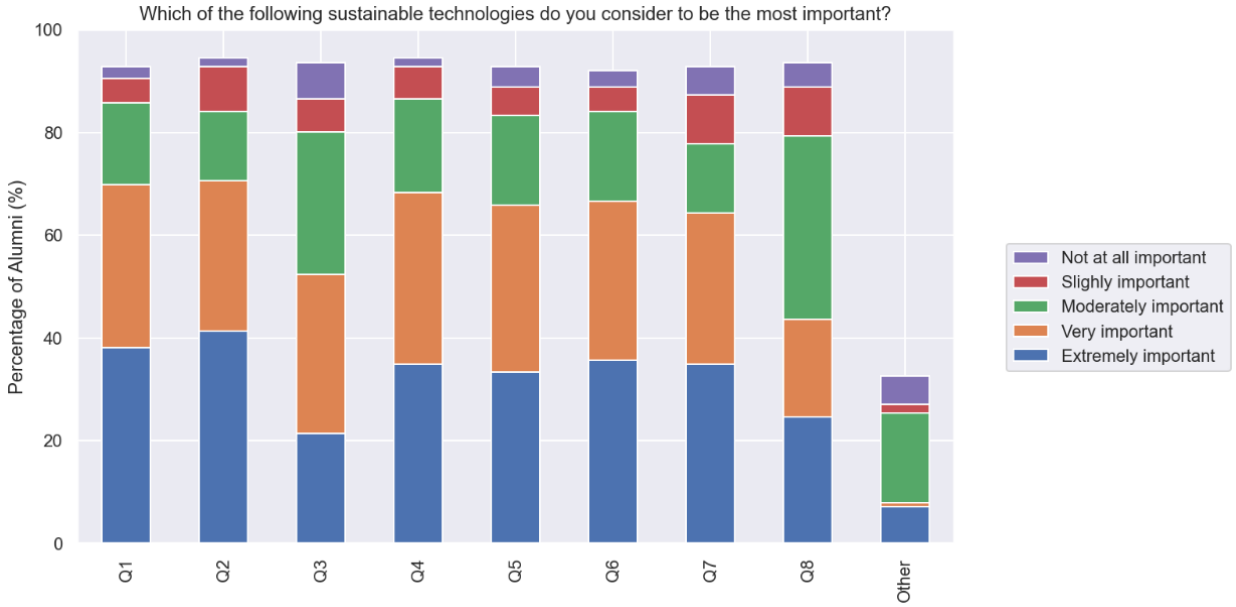

Figure 11. *Alumni results for the question "Which of the following sustainable technologies do you consider to be the most important?"*

Discussions and Conclusions

BSU has made strides in becoming a diverse institution with evidence-based approaches to education. In this endeavor, BSU has acknowledged the difference in the alumni and student data regarding the implementation of sustainability concepts in both the past and present curricula as well as in the alumni workforce. The most recent data has shown that the ALMs are slowly increasing engagement in engineering students, though with some notable differences in responses based on gender — in the alumni demographics, there were only 15% of female participants, while in the student data, there was about 20% of practicing female engineers. Despite the 5% difference in the female population, there are similar trends found in both the alumni and student data for each semester. In all the post-surveys for the student data, women were found to be more interested in applying sustainability than men. This can be the result of ecofeminism or the ALMs being more effective with women than with men. Furthermore, previous graduating cohorts were exposed to fewer ALMs and, by extension, less education regarding sustainability. With sustainability growing in popularity across multiple disciplines, alumni participants are now in favor of adding sustainability concepts into their design work. This directly implies that for students to succeed after their undergraduate career, it is essential that they learn about applying sustainability concepts in their undergraduate career (earlier) rather than in their professional career (later). After exposure to newer ALMs, students were able to acknowledge how crucial it is to add sustainability into their curriculum. The surveys given to alumni and current engineering students can help BSU visualize this increase in engagement, and for the BSU mechanical engineering department to stay abreast of the latest areas of concern in the industry, there must be a change in the curriculum to include sustainability concepts that are both repeated in multiple courses and progress in complexity as the student advances throughout their degree.

The department must also implement the horizontal method and apply sustainability concepts to focus on a student's specific field. This can also include adding more real-life examples through the ALMs, including speakers who actively work in the field, or tours of sustainability practices in motion. If these changes are made, one direct positive result this will also have will be to lift the confidence of female engineers when applying sustainability into their designs; unlike the alumni students who had no coverage of sustainability, newer graduating students will have the exposure and experience to confidently apply the practices into their line of work — and though the upcoming cohort has already had more exposure than previous graduates, there are still many avenues left to explore regarding the successful implementation of sustainability education in the existing curricula.

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