MEASURING ENGINEERING STUDENTS' ENGAGEMENT IN SUSTAINABILITY DESIGN CONCEPTS

by

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The following individuals read and discussed the thesis submitted by student Karen Aide Perez, and they evaluated the student's presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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DEDICATION

Dedico esta presentación a mi familia. Vinieron a los Estado Unidos con el sueño de verme como profesional, y con trabajo, dedicación y esfuerzo les dedico mis logros de universidad. Gracias a mi familia: Fernando, Vicky, Alondra y Güero por aguantarme durante muchos años de estrés y aprendizaje. Y como dijo mi ama, ponte las pilas. Y como dijo mi papa, vivilla desde chiquilla. Gracias por su apoyo y amor.

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ABSTRACT

Within industries, governments, and accreditation organizations, there has been a push to incorporate sustainability concepts into their models. Universities like Boise State University (BSU) have already begun to place greater emphasis in inclusion of sustainability concepts in different engineering department curricula. As part of this effort, BSU plans to redesign courses to integrate sustainability concepts using active learning modules (ALMs) suited for each grade level and discipline. The effectiveness of these modules will be evaluated across disciplines. In support of this larger goal, the work in this study will specifically focus on mechanical engineering students.

A survey instrument was developed for distribution to BSU mechanical engineering students and mechanical engineering alumni to investigate their knowledge and attitudes towards these topics but particularly in sustainable practices. In addition, interviews were conducted where alumni were able to discuss their values and learning retention with sustainable development. It is estimated that there will be approximately 200 participants across both the student and alumni survey. By applying a mixed methods approach to the survey instrument, students and Boise State Engineering alumni will have the opportunity to express their perception of BSU's current integration of sustainability concepts. The responses will allow mechanical engineering courses to accurately and effectively present sustainable concepts. The results will be presented with demographics Likert-scaled bar graphs that includes the interpretation of the p-value, standard deviation and mean. This paper addresses the challenges and issues that academic and industry facilities face when bridging these engineering practices with these concepts.

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CHAPTER ONE: INTRODUCTION

Statement of Problem

Sustainability was coined in 1987 by the Brundtland Commission to tackle the problem of environmental degradation (Oxford: Oxford University Press, 1987). Sustainability has grown in popularity, especially in the academic world (Rosen, 2013). Particularly in STEM, sustainability is a viable concept to understand as the new environmental standards and technologies are evolving to meet the components of sustainability. There have been many attempts to introduce sustainability into higher education, as many universities have successfully implemented sustainability concepts into their university curriculum (Issa, 2017). There have been challenges that arise when implementing sustainability into the curriculum. Challenges include the lack of engagement students have when being introduced to sustainability. The lack of student engagement lies in the inability to provide industry-related examples to meet the needs of practicing engineers. There is a disconnection in introducing students to fundamental sustainability concepts that they will later be able to use in industry-related design work. Exposure to learning environments outside of the classroom will enable their engagement with sustainability.

With the increase in engagement, students will be able to interpret their interests and use sustainability concepts in their design work. The increase in engagement begins with restructuring courses to include more active learning modules (ALMs) in the classroom that connect to industry practices. The active learning modules must be intersected with real-life examples from Boise State University (BSU) alumni to create that relationship with the industry and academic world. This research study will use ALMs to increase engagement amongst students by observing the trends of demographics related to gender, age and ethnicity that arise from students and alumni participants.

Research Questions

Based on previous research outcomes, literature has shown that universities have researched ways to integrate sustainability and sustainability development in engineering education (Ceulemans et al., 2011; Galambosi & Ozelkan, 2011). In addition, universities have investigated their students' motivation on learning sustainability (Lanziner, 2018). The American Society of Mechanical Engineers' (ASME) conducted a survey in 2009 to find trends related to sustainability in mechanical engineering students and employers. The study suggested that the use of sustainability in both industry and education is increasing over time (Rosen, 2013). Although there have been studies that examine an industry's use of sustainability, undergraduate programs have not tied that research finding by presenting real-life examples when teaching sustainability. There is a lack of information on the effectiveness of using real work examples to improve student learning related to sustainability concepts. ALMs have shown in the past to increase student engagement and student retention (Freeman et al., 2014).

At BSU, ALMs have been used to teach sustainability instead of traditional lecture to improve engagement (Salzman et al., 2018). The initial ALMs used in ME courses show that students were captivated with hearing real world examples as opposed to theoretical concepts and could benefit with more case studies to maximize student knowledge and attitudes. From this, we can infer that universities should strive to bridge the gap between industrial applications and academia to maintain student engagement. As a result of this foundational information, the following questions have been developed.

1. How do we encourage engineering students' engagement in sustainability to improve learning?
2. Are the sustainability topics used in ALMs relevant to industry applications for mechanical engineering?

The purpose of this research was to investigate answers to these questions. Particularly, this research sought to find the most effective instruction methods to enhance engineers' understanding of sustainability concepts so that they can effectively teach current engineering students at BSU. In past research, methods were created to intertwine sustainability into technical programs, and these studies focused on students' awareness, knowledge, and attitudes towards these concepts (Lanziner, 2018; Tang, 2018). The aim of this study is to identify factors that increase student engagement by examining current engineers who are in their respective industries and have used these concepts in real-life scenarios. Understanding the views of professional engineers who use sustainability in real-world applications can give BSU the information it needs on how to change its curricula to allow students to become better engineers.

Significance of Study

Boise State University's mechanical and biomedical engineering department have been on the verge of recreating the academic program to have a more themed learning track (McNeilly et al., 2020). The improved curriculum allows BSU to be in an excellent position to begin the integration of adding sustainability concepts (McNeilly et al., 2020). While sustainability is a concept that can be applied to a diverse curriculum, BSU has had great success in adding sustainability concepts to the civil engineering department (Salzman et al., 2018). Civil engineering students were able to recognize sustainability as an important topic but lack consistency with understanding sustainability throughout each grade level (Salzman et al., 2018). To improve learning, it was suggested to infuse ALMs into lectures to lead students to incorporate sustainability principles into their design work (Salzman et al., 2018).

The success of adding sustainable concepts has been recognizable by students, but there has been a lack of understanding of where these new skills will be applied when working in the industry. This study is significant to students, especially mechanical engineering students because it investigates past BSU mechanical engineering alumni and their experience with sustainability. This study will be significant to institutions like BSU to understand students' perceptions of these concepts. This study can be used to be better instill ALMs that will benefit students in upcoming years by adding information that will be useful to the student.

Overview of Thesis

This thesis has been organized in four chapters to fully understand student’s engagement in sustainability concepts based on demographics and understand alumni perceptions in sustainability from their past work. Chapter 2 describes the literature review that was used to shape the research questions for this study. The literature review investigates the implementation at other universities and their successes in developing instruction in sustainability, the understanding of student cognitive learning and approaches of implementing sustainability. The literature review founded in Chapter 2 is used to identify the research design and research questions.

Chapter 3 describes and outlines the explanation of the mixed method research design, an explanation of the survey, a description of the participants, overview of data collection and the analytical methods used to interpret the data. The quantitative data was obtained from pandas, a software library written for python that is mainly used for data analysis and interpretation of data frames. The quantitative data was interpreted through the evaluation of data statistics (ie. p-value, mean, standard deviation, skewness, and kurtosis) and manipulation of bar diagrams to understand the trends found. To analyze qualitative data, alumni interviews were recorded, transcribed, coded with NVIVO, and assembled into themes addressing industry – sustainability usage from an alumni perspective. This chapter includes an explanatory definition of the survey instrument along with data collection and a description of the participants chosen for this study.

Chapter 4 highlights gathered data from the alumni and student surveys as well as the results from the alumni interviews. The results found from the survey will be used to evolve the curriculum to better suit future students. Chapter 4 explores the outcome in relationship to the following research questions:

1. How do we encourage engineering students' engagement in sustainability to improve learning?
2. Are the sustainability topics used in ALMs relevant to industry applications for mechanical engineering?

The results found related to the research questions were divided in demographics to further understand the participant's perspective. The background of participants can change the frame of reference in using sustainability design in their work. The results may vary due to their past experiences and background. Alumni participants were exposed to sustainability in their work field rather than learning the fundamentals of sustainability in school. Understanding the demographics of the participants alongside their engagement can improve the curriculum in a positive way.

The last chapter (Chapter 5) includes the discussion and conclusion of the study. The discussion includes analyzes the pre- and post- data for student data, the survey results from the alumni data and include the instructor’s narrative from teaching ALMs. The limitation and suggestions for future research related to the results are included in the last chapter.

CHAPTER TWO: LITERATURE REVIEW

Introduction of Sustainability

The concept of sustainability was introduced in 1987 by the Brundtland Report, where it was described as “the ability to make development sustainable is to ensure that it meets the needs of the present without compromising the ability of the future generations to meet their own needs**”** (Oxford: Oxford University Press, 1987). The Venn diagram below depicts the basic analytical approach related to the sustainability pillars: environmental, social, and economic (colloquially known as people, planet, and profit) (Barbier, 1987). The “triple bottom line” is often associated with the balance of the three pillars (Elkington, n.d.). As shown below, the Venn diagram is often used as a graphical illustration of the intersecting elements that comprise the concept of sustainability (Penn & Fields, 2017).

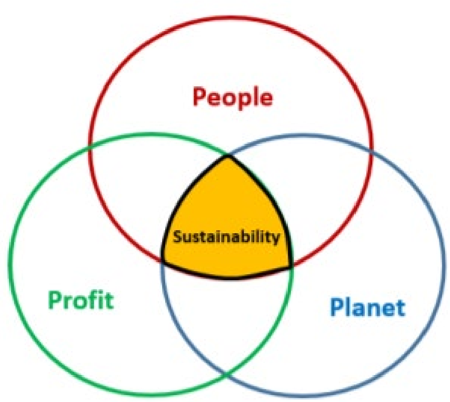


Figure 2.1. Venn diagram for sustainability

The Brundtland Report was created to find ways to resolve human environment, natural resources, and to protect economic and social development (Oxford: Oxford University Press, 1987). Despite coining sustainability, it was John Elkington that coined the Triple Bottom Line (TBL) (Elkington, n.d.). Elkington created the TBL in hopes to mobilize consumers to add pressure on business companies about environmental issues (Elkington, n.d.). The TBL starts with the outbring of people that includes the idea of adding value to a community sense. In the Brundtland Commission, the rapid growth of the worldwide population is mentioned multiple times to unveil ways to minimize the population (Oxford: Oxford University Press, 1987). The people pillar is far more than looking at the population, it's about bringing fair wages or providing health care to the people (Alhaddi, 2015). Before the recognition of TBL, industries would focus more on the economic costs and often ignore social responsibility (Alhaddi, 2015).

The economics pillar is often associated with organizations. The economic pillar refers to the economic impact on an organization's business practices (Elkington, n.d.). Examples includes financial performance, sale growth, cash flow and shareholders. The last pillar of TBL includes the environmental line. Many people especially students often relate sustainability to environmentalism. The environmental focuses on the minimization of energy and waste production to reduce ecological footprint (Correia, 2019). A few scholars have argued that the environmental pillar is the most important dimension due to the dependence the other pillars have on environment. The triple bottom line is best introduced to first- and second- year students as an effective way to learn about sustainable engineering design (Penn & Fields, 2017). Using the triple bottom line prepares students for more detailed evaluation of sustainability in upper-level courses (Penn & Fields, 2017).

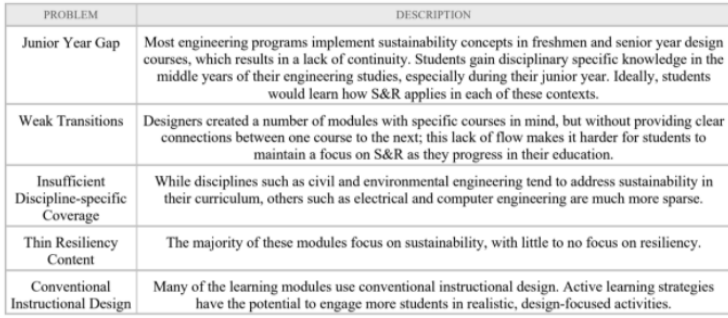
In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development which formed the 17 sustainable development goals (SDGs) that can end poverty by 2030 (*THE 17 GOALS | Sustainable Development*, n.d.). SDGs is a universal framework that supports global strategies that can improve health, education, and reduce inequality while also tackling climate change (THE 17 GOALS | Sustainable Development, n.d.). Embedding the SDGs within a curriculum change will help enhance human capital and increase the number of individuals who live sustainably, which can ultimately help achieve the UN's goals for a better future (Leal Filho et al., 2019). Of relevance is goal #4, Quality Education, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. In pursuit of teaching students, the TBL, will promote goal #9, Industry, Innovation, and Infrastructure, which promotes inclusive and sustainable industrialization.

Sustainability in Higher Education

In recent years, the concepts of sustainability have piqued the interest of many professional communities and have been emphasized in workforce development and student education (Malik et al., 2019; Mintz & Tal, 2014). With the interest in sustainability rising, many universities have begun integrating sustainability concepts into their engineering curriculums (Aurandt & Butler, 2011; Galambosi & Ozelkan, 2011; Issa, 2017). There are two primary approaches used to integrate sustainability into the existing engineering programs: vertical integration and horizontal integration (Aurandt & Butler, 2011; Ceulemans et al., 2011; Galambosi & Ozelkan, 2011; Issa, 2017). Vertical integration introduces sustainability concepts by developing new courses in the engineering program curricula, which is typically accomplished by adding these courses as electives (Aurandt & Butler, 2011; Ceulemans et al., 2011; Galambosi & Ozelkan, 2011; Issa, 2017). The vertical approach does not require significant training to instructional faculty across the curriculum as the integration is often focused on a separate course in the curriculum (Ceulemans et al., 2011). In contrast, horizontal integration includes the addition of sustainability concepts into multiple existing courses (Aurandt & Butler, 2011; Ceulemans et al., 2011; Issa, 2017). The horizontal approach revises existing course content to include topics related to environmental and social issues as well as teaching students about tradeoffs that exist when considering the triple bottom line (Issa, 2017). Some common challenges of the horizontal method include limited instructor awareness of sustainability concepts in a specific discipline, instructors misunderstanding the meaning of sustainability concepts, and instructors simply not believing that sustainability concepts are worth the effort of teaching (Ceulemans et al., 2011). The horizontal method, despite its challenges, is preferable to the vertical method (Ceulemans et al., 2011); in the horizontal method, students are introduced to a concept multiple times in a progressive structure that improves learning and retention. This ultimately helps both students and instructors learn about sustainability concepts and their applications in both academic and professional settings.

In the pursuit of integrating sustainability concepts into their curricula, select undergraduate programs in other universities have tried to implement the horizontal method into their approach. At Michigan Tech, an established program called the Sustainable Futures Institute (SFI) focuses on providing an outreach to research and education to provide solutions to sustainability challenges (Kumar et al., 2005). The SFI focuses on providing sustainability emphasis in graduate and undergraduate curricula (Kumar et al., 2005). These modules created awareness among mechanical engineering students, but experts from Michigan Tech suggested applying more real-world learning experience should be required in curricula to increase engagement in sustainability (Kumar et al., 2005).

More locally, Salzman et al. (2018) revealed the dilemma the Civil Engineering department at BSU faced during the implementation of integrating sustainability concepts using the horizontal approach. While sustainability concepts are not a primary focus in the civil engineering curriculum, many students were able to recognize the significance of understanding sustainability and sustainable design practices. Despite this, it was shown that many students struggled to develop a lasting relationship with sustainability and resiliency. Figure 2.2 defines problems that the civil engineering department at BSU faced during the introduction of these topics (Salzman et al., 2018). Many engineering curricula touch on sustainability concepts, especially in introductory courses and senior level courses, but the lack of continuous coverage and weak transitions have led to a lack of connection in these topics. In essence, the less students are exposed to the concept, the less likely it is that a student will be able to apply sustainability to their designs. It is believed that with the addition of more engaging teaching methods across the required courses in these disciplines, students will better understand the significance of S&R concepts and how to best apply them in their professions (Salzman et al., 2018).



PROBLEM	DESCRIPTION
Junior Year Gap	Most engineering programs implement sustainability concepts in freshmen and senior year design courses, which results in a lack of continuity. Students gain disciplinary specific knowledge in the middle years of their engineering studies, especially during their junior year. Ideally, students would learn how S&R applies in each of these contexts.
Weak Transitions	Designers created a number of modules with specific courses in mind, but without providing clear connections between one course to the next; this lack of flow makes it harder for students to maintain a focus on S&R as they progress in their education.
Insufficient Discipline-specific Coverage	While disciplines such as civil and environmental engineering tend to address sustainability in their curriculum, others such as electrical and computer engineering are much more sparse.
Thin Resiliency Content	The majority of these modules focus on sustainability, with little to no focus on resiliency.
Conventional Instructional Design	Many of the learning modules use conventional instructional design. Active learning strategies have the potential to engage more students in realistic, design-focused activities.

Figure 2.2. Problems with infusing sustainability and resiliency into engineering curricula

Student Learning

Bloom's taxonomy is a notable framework used to describe the different levels of cognitive understanding of a subject, especially when used in tandem with engaging content (*Bloom's Taxonomy | Center for Teaching | Vanderbilt University*, n.d.). Figure 2.3 shows a six-tier diagram that illustrates the levels of progression in a student's comprehension of a specific concept (*Bloom's Taxonomy | Center for Teaching | Vanderbilt University*, n.d.). First- and second-year courses typically focus on the first three tiers of remembering, understanding, and applying. These courses allow most students to form a basic understanding of sustainability and recall its definition after being exposed to the concept. Sustainability is also often associated with the environmentalism pillar; therefore, students need guidance to understand and apply all the TBL concept in their design work. With new course content, students will be encouraged to consider sustainability concepts as they relate to engineering practice. Following this progression, sophomore-level students are expected to apply and implement sustainability to their class work. Freshman-level students should be able to comprehend the sustainability design concepts being presented.

Bloom's taxonomy has proven to have a relationship with engagement. When a student shows engagement in a material, the student is likely to have a higher level of comprehensive and cognitive development (Moore & Sanchez, n.d.). When moving away from being teacher-centered (lower-levels) to student-centered (upper-levels) activities such as active learning modules enhances deeper learning and provides students focused career goals (Yang & Koszalka, 2016). The utilization of Bloom's taxonomy to enhance student engagement can also assist the instructor to provide material that facilitates the delivery method to enhance student engagement (Moore & Sanchez, n.d.). Understanding Bloom's Taxonomy related to engagement and ALMs allows for better ALMs shown in the curriculum.

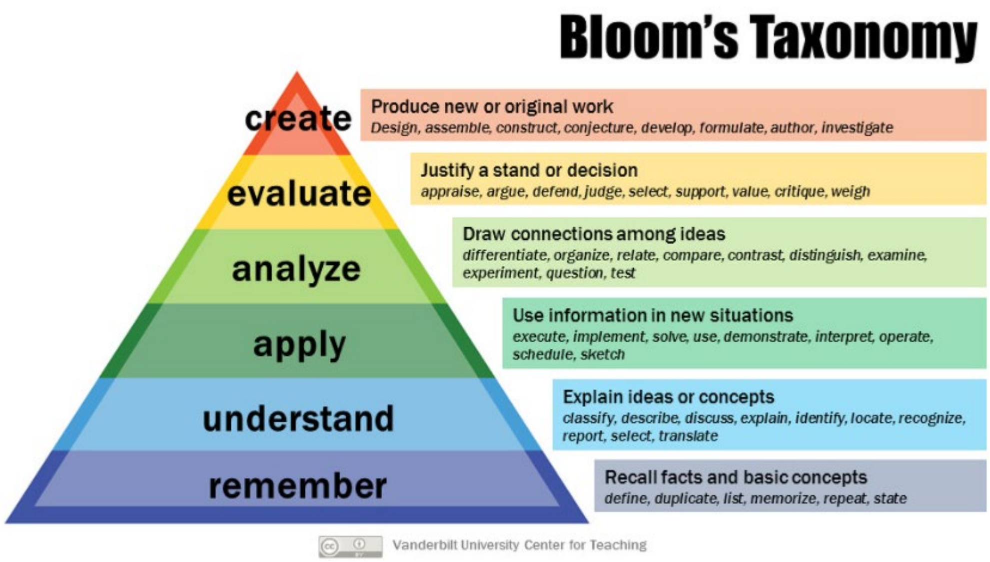


Figure 2.3. Six-tier diagram of Bloom's Taxonomy created by Vanderbilt University Center for Teaching

Though this study will not be evaluating the last three tiers of Bloom's Taxonomy, it is still important to illustrate them for future studies. The concepts of Bloom's Taxonomy can be used in future research studies to further emphasize student learning of sustainability concepts across the curriculum. The last three tiers can easily be achieved with more individual and group activities (Crowe et al., 2008); which can be implemented using ALMs. Understanding how students' progress in the tiers of remembering, understanding, and applying will be beneficial to implement sustainability concepts suitable for freshman and sophomore-level students.

Sustainability in Mechanical Engineering

As part of the work on a new NSF award, the BSU mechanical engineering program will incorporate sustainability concepts using a horizontal integration strategy originally piloted in the Civil Engineering program. Instructors will embed these concepts into the course assignments and students will learn to apply sustainability within the context of multiple engineering courses across the curriculum. This implementation will serve as a guide to other departments in embedding sustainability strategies in courses.

The Mechanical and Biomedical Engineering Department has recently modernized the curriculum for the BS in Mechanical Engineering. The primary goals of the new program are to develop more experiential learning opportunities, allow more flexibility, and create focused, themed learning tracks in the curriculum (McNeilly et al., 2020). The modernization of the program provides a significant opportunity to embed relevant concepts of sustainability into the curriculum using the horizontal method as they align with the themed learning tracks. At BSU, instructors incorporate Bloom's taxonomy by the consistent and logical introduction of sustainability concepts throughout the curriculum. Likewise, through the repetition of sustainability concepts, it is reasonable to assume students will also be able to better understand the concepts and apply them to their design work. At BSU, the Mechanical and Biomedical Engineering

Department aims to accomplish this through the introduction of a new, modernized program that incorporates sustainability content using engineering examples to assist student comprehension. The new curriculum will provide the opportunity to tie in the new sustainability concepts at multiple levels.

Active Learning Modules and Sustainability

The traditional method of teaching has predominantly been done through lecturing. This method has been proven to be effective for transferring knowledge, but it has also shown that students are less likely to be fully engaged with material presented in this manner (Freeman et al., 2014). Student activity during lectures is limited and passive due in part due to instructor time constraints and notetaking, which serves only to supplement the retention, not the application, of the material. Active learning modules (ALMs) aim to solve this by restructuring the traditional format. ALMs can most simply be defined as strategies that actively present engaging activities such as discussions in class, case studies, and presentations. 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 normal rate; these techniques also have the added benefit of increasing student learning compared to traditional lecturing (Freeman et al., 2014). The results also show that test scores improved by 6% with active learning sections (Freeman et al., 2014).

A significant recent education reform project (WIDER-PERSIST) at BSU, funded by the NSF, promotes changes in the culture of teaching that focus on student learning (Shadle et al., 2017). This project works with adopting evidence-based instructional practices (EBIP) into course material. The process of developing ALMs is a variation of EBIP that will align with the BSU culture of improvement in teaching and learning.

The implementation of sustainability concepts throughout the Mechanical Engineering curriculum will occur in several steps. As shown in Figure 2.4, the University of Surrey developed a three-tier approach to teaching sustainability (Azapagic et al., 2005). These steps include the traditional way of introducing these topics with the horizontal integration. As illustrated below, the elements of this approach include lectures, tutorials, and specific case studies for sustainability in specific disciplines. This is then followed by the larger integration into the overall curriculum. This method is effective because of the logical organization of the steps; in the introduction phase, students are taught the key learning areas through a series of lectures and tutorials (Azapagic et al., 2005). The second-tier exposes students to more in-depth information on sustainability concepts, which enables students to develop sustainable solutions. Through this structuring, the Mechanical Engineering curriculum uses ALMs in tandem with horizontal structuring as demonstrated below.

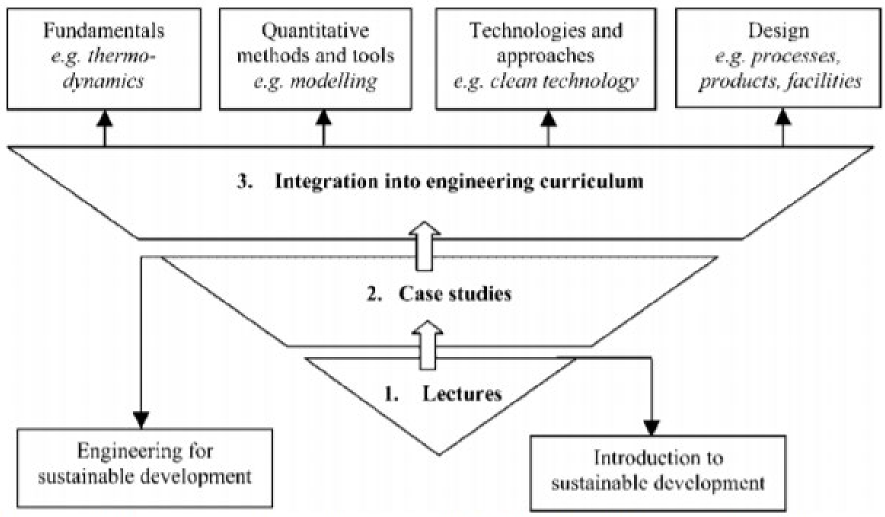


Figure 6. The three-tier approach to teaching sustainability developed by the University of Surrey (adapted from Azapagic, 2001).

Figure 2.4. Three- tier approach to teaching sustainability

The last tier focuses on the overall integration of infusing sustainability concepts into the engineering curriculum. This phase is the most challenging phase for a few reasons; the primary issue faced here is the lack of teacher understanding of sustainability concepts and the relative absence of thorough case studies in higher division courses. Although this tier poses the most difficulties, the successful application of this tier will afford teachers and students alike a more robust understanding of sustainability concepts. When used successfully, this approach has been shown to provide outcomes that create connections in engineering applications to sustainability concepts (Azapagic et al., 2005). As the creator of this strategy, Azapagic recognized that the beginning stages of applying the horizontal approach involves providing discussions and case studies to students. For the purpose of this research, tiers one and two will be evaluated thoroughly before introducing these concepts throughout the whole curriculum.

The new modules will be created as ALMs and will be suitable for each discipline and grade level. Because sustainability has been taught in the past in civil engineering courses, the mechanical engineering department will use existing ALMs to develop modified versions that aligns with the mechanical engineering curriculum. The ALMs will include adding guest speakers with experience using sustainability concepts in real-life applications, utilizing case studies, and developing in-class activities. This research will focus on understanding student knowledge and attitudes from ALMs.

Demographics and Sustainability

BSU has seen an increase in female enrollment, specifically those majoring in mechanical engineering and engineering plus. In the academic year 2020-2021, about 38% of women enrolled in STEM-related fields at BSU, creating a 10% increase since 2016-2017 (*STEM Enrollment Demographics - Institute for Inclusive and Transformative Scholarship*, n.d.). 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 (Clark et al., n.d.). Despite these stereotypes, women statistically receive a higher course grade than men and are likely to outperform men in science courses (Bloodhart et al., 2020). A study found that collaborative learning and hands-on experimentation have increased girls' confidence and interest in the STEM field (Fancsali & Froschl, 2006; Shuen et al., 2011). Adding ALMs to BSU's engineering curriculum can further enhance women's confidence levels in STEM.

The stereotypes found in 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 (Meinzen-Dick et al., 2014). 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 (Meinzen-Dick et al., 2014). Understanding confidence concerns based on gender will help with understanding sustainability engagement presented in the ALMs.

Looking at the demographics based on ethnicity, minority groups often lack the understanding of the TBL. Although there is limited research related to ethnicity views on sustainability, there is study that suggests that ethnic groups are less likely to be concerned with environmentalism unlike bigger majority groups (Liere & Dunlap, 1980). This ideology comes from the lack of resources (i.e. wealth and education) minorities have thus becoming less concern over environmental beliefs (Medina et al., 2019). Minorities are often focusing on survival that causes them to use their time on other resources (Medina et al., 2019). Based on a study from the National Survey on Environment, statistically African Americans and Latinos/Hispanics have significantly shown less concern over environmental issues (Johnson et al., 2016). There is a lack of evidence that minorities concerning over economic and sociocultural issues that arise from the TBL. Despite minorities lack of interests of the environmental issues, it's possible there is interests in the economic and social aspects of sustainability.

There are different trends when it comes to age. Research shows that a person's attitude and behavior towards sustainability changes relative to age (Wiernik et al., 2013). With sustainability being a new term, it's expected that the younger generation may be more profound and willing to apply the methodologies that persist with sustainability. This is expected due to their drive to learn new material and be amongst new opportunities (Liere & Dunlap, 1980). Environmental issues require the effort to change and with a younger individuals' eagerness to learn, they are more likely to fulfill that change (Wiernik et al., 2013). The younger generation may be willing to learn about sustainability, but they lack knowledge to place into it into action (Johnson et al., 2016; Wiernik et al., 2013). The older generation is likely to be motivated by social norms and be willing to perform with environmental issues (Wiernik et al., 2013).

Previous Work

BSU has used the horizontal approach in civil engineering in past years. The standard approach for the civil engineering curriculum included relatively minimal coverage of sustainability concepts and/or using the vertical integration by adding a course dedicated to sustainability (Salzman et al., 2018). Interviews were conducted with senior civil engineering students to better understand attitudes toward S&R concepts. The interview questions were based on the students' knowledge by describing their understanding of S&R concepts from the civil engineering courses (Salzman et al., 2018). A common theme found in the study was that students were able to describe what they learned from their participation in the course. Some even related their senior design project and internship experience back to S&R concepts. Several participants recognized that the case studies presented were examples of failed projects that were not sustainable, rather than good sustainable examples (Salzman et al., 2018). 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(Salzman et al., 2018).

For this current project, the methods developed in the civil engineering project will be applied to the introduction of sustainability into the mechanical engineering program. BSU’s improved undergraduate curriculum has allowed BSU to be well-positioned to adopt highly relevant sustainability course content. To maximize students' learning, particularly in the freshman and sophomore years, active learning techniques should be adopted to encourage student engagement with these topics.

CHAPTER THREE: METHODS

Research Design

With the rise of sustainability within engineering, there has been a push to understand the attitudes and behaviors regarding sustainability in practicing engineers (Rosen, 2013). BSU has participated in this effort by adopting the beginning stages of changing their curricula to apply more sustainability concepts. As seen in Chapter 1, the research questions are based on student engagement and the connection with mechanical engineering industry practices. Figure 3.1 shows how this research will address these questions. Students who experience the modified ALMs were asked to participate in a survey related to their knowledge and attitudes to sustainability. The post results found in Spring 2021 are used as the baseline data for students' knowledge and attitudes. In Summer 2021, a survey was conducted to BSU mechanical engineering alumni to determine ways that sustainability is used in industries relevant to BSU students. For those interested in providing an in-depth response related to their sustainability usage, there were opportunities to share their responses in an online interview via Zoom. The interview responses were used to further understand industry practices used by Boise State Alumni and the challenges they faced to learn sustainability practices. The students in Fall 2021 and Spring 2022 were presented with different ALMs with similar discussion lectures as shown in Table 3.1. Before presenting the new ALMs, students were invited to perform a pre-data collection. After the new ALMs, students were invited to participate in a post-data collection. The students who participated in the pre- and post-survey will be evaluated by comparing the changes in perspective from the introduction of ALMs. The survey data for these student cohorts will be analyzed and compared to the Spring 2021 results and conclusions will be determined.

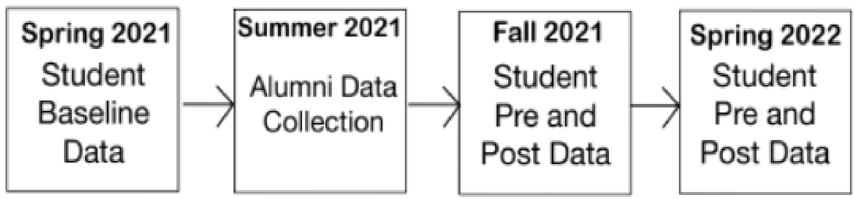


Figure 3.1. Research Thesis Outline

To increase engagement, the ALMs were changed to have different elements of sustainability practices. The ALMs presented in each semester are shown in Table 3.1. In the past, sustainability was introduced to the civil engineering students; the lectures used in that study were slightly modified to be used in the cohort of Spring 2021 students. The modification included using the introduction of alumni experiences and in-campus examples. An alumnus who worked in industry in various projects presented in a lecture; the most notable projects related to sustainability included the installation of commercial-grade refrigeration systems. The component of adding an alumni lecture was used to increase the engagement of students by providing the students an insight of a career that utilizes sustainability. Students were highly engaged with this introduction of an alumni guest speaker.

Table 3.1. Sustainability Modules Added for Each Semester

Module	Description	Semester Introduced
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
Sustainability Study Abroad Informational	During in-class lecture, the students were introduced to the sustainability abroad program, The Green Program (TGP), and hear about TGP Alumni about their experience with the program.	SPRING 2022
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 and SPRING 2022

The students of Fall 2021 had a slightly different approach. The lecture was altered to incorporate teachings of different renewable energy, specifically in hydropower. It was noted that students in Spring 2021 struggled with understanding how to apply sustainability in design concepts. Based on this observation, the lecture for the group of Fall 2021 was improved to include more examples of sustainability. In 2013, The Association for the Advancement of sustainability in Higher Education (ASHEE) published a blog to showcase 10 ways to integrate sustainability into the curriculum (Changxin Fang, 2013). The blog described the incorporation of introducing sustainability practices by using the local university as a classroom (Changxin Fang, 2013). In Fall 2021, BSU was awarded a silver rating for sustainability efforts on campus through a third-party accreditation, ASHEE, that uses the Sustainability Tracking, Assessment and Rating System (STARS) to evaluate their sustainability efforts(*Boise State University | Scorecard | Institutions | STARS Reports*, n.d.). Student recognition of this award can also serve to increase engagement with sustainability practices presented in the curriculum. The Environmental Health, Safety and Sustainability Department created a virtual walking tour that pinpoints BSU campus sustainability efforts. Adding the element of a walking tour provides students a visualization of their home university's sustainability goals, which can help springboard future potential projects.

ASHEE’s blog included the integration of studying abroad and introducing students to learning about sustainable opportunities abroad. BSU’s study abroad office offers a program called The Green Program (TGP), which teaches students about sustainable development by connecting them with universities and companies around the world. Introducing students about these programs can help students become more engaged in learning about sustainable development and increase their involvement opportunity.

Participants

This project aimed to distribute the surveys to Boise State mechanical engineering alumni and current students who are taking Design 1 (ME 287) and Communication in Design Thinking (ENGR 180). ME 287 is an introductory class for mechanical engineering students that focuses 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. Because both classes teach practicing engineers about ethics and design concepts, these courses are ideal to introduce sustainability concepts. For the student study, there are two collective groups of people that will participate in the study. Those affected by this study will be students who are enrolled in a combination of required and elective courses in specific engineering programs of Engineering Plus, and Mechanical and Biomechanical engineering students and BSU's mechanical engineering alumni. All students who have taken ME 287 and ENGR 180 have been invited to complete the survey. Although it is not required for the students to participate in the survey, extra credit was offered to the students as an incentive to do the survey and receive a higher response rate. The student participants were selected by their enrollment in ENGR 180 and ME 287. These activities will include using case studies, providing guest speakers, and further explaining sustainability modules.

BSU ME alumni were invited to participate in a separate survey designed for engineers. Alumni were given a choice to participate in the survey without an incentive. Those who showed interest in the survey were invited to participate in an additional interview to better understand their perspective and learning difficulties with sustainability design.

Student Evaluations for Survey

Each sample size (N) changes per semester since it is based on the 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 to gain a higher response rate. The student participants were selected by their enrollment in ENGR 180 and ME 287. The total population of student enrollment in ME

287 and ENGR 180 for the entire study 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. The data from Spring 2021 will be used as a baseline data to further understand student's engagement with sustainability. For Spring 2021, in ME 287 there were 27 students enrolled in the course and 42 students enrolled in ENGR 180. The surveys received a high response rate of 53% and yielded a sample size of 69. Table 3.2 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% were prefer not to say. Based on Table 3.2, 51% were sophomore students with the leading category of junior students of 24.3%. While ENGR 180 and ME 287 are provided for freshman and sophomore students, students are able to take this course regardless of their education status. Common reasons for other students besides freshman and sophomore students taking this course include transfer students and students having multiple credits before reaching their upper division courses.

In the education major category, most students were mechanical engineering students with the result of 62.2% and various other majors, followed by Engineering Plus by 7%. The "Other" category was students who were undecided. ENGR 180 and ME 287 are courses that were directed to students who are majoring in mechanical engineering and Engineering Plus. As expected, most of the students were white, who made up 78.4% of respondents. Lastly, students were approximately between ages 18-25. The median age was 18-20 accounting for 62.2% of respondents, and the percentage of students aged 21-25 was 18.9%.

Table 3.2. 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
Age	18-20	23	62.2
	21-25	7	18.9
	26-30	3	8.1
	31-35	1	2.7
	Over 60 years of age	1	2.7
Ethnicity	White	29	78.4
	Latino or Hispanic	3	8.1
	Prefer Not to Say	1	2.7
	Other/Unknown	2	5.4
	Asian	2	5.4
Education	Freshman	6	16.2
	Sophomore	19	51.4
	Junior	9	24.3
	Senior	2	5.4
	Other	1	2.7
Major	Mechanical Engineering	23	62.2
	Electrical Engineering	2	5.4
	Civil Engineering	3	8.1
	Engineering Plus	7	18.9
	Other	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 to better identify the outcome of active learning modules 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 3.3 shows 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 3.4 outlines 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 male, women, and prefer not to say are equivalent to the post-survey. The average percentage was 77.7% male, 20% women, and 2.9% prefer not to say. The difference of average percent from gender demographics in male was about 0.6%, 2.4% for women, and 1.7% for prefer not to say.

Unlike the Spring 2021 cohort, the Fall 2021 cohort in the education levels were mixed. On average, freshman, sophomore, and junior students made up the majority of respondents. The percentages were 21.2% freshman, 32.9% sophomores, 35.3% juniors. In Spring 2021, the majority of students were sophomores. The major difference in this cohort was that sophomores made up 18.5% of students. Compared to the baseline data (Table 3.2), freshman students increased by 5% while the number of juniors increased by 11%. The number of mechanical engineering students also increased at 16.6% while the number of engineering plus students decreased to 9.5%. By ethnicity, Caucasians in the engineering courses made up 83.5% of students, which was more than the previous semester. The number of Latinos and Hispanics is growing but are still considered a minority at Boise State University. Latinos or Hispanics currently enrolled in ME 280 and ENGR 180 courses were 7.1% of students.

Table 3.3. 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
Age	18-20	61	71.8
	21-25	20	23.5
	26-30	1	1.2
	31-35	2	2.4
	36-40	1	1.2
Ethnicity	White	71	83.5
	Latino or Hispanic	6	7.1
	Prefer Not to Say	5	5.9
	Other/Unknown	1	1.2
	Native Hawaiian	2	2.4
Education	Freshman	18	21.2
	Sophomore	28	32.9
	Junior	30	35.3
	Senior	8	9.4
	Other	1	1.2
Major	Mechanical Engineering	67	78.8
	Civil Engineering	2	2.4
	Engineering Plus	8	9.4
	Other	8	9.4

Table 3.4. 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
Age	18-20	19	54.3
	21-25	13	37.1
	31-35	2	5.7
	36-40	1	2.9
Ethnicity	White	30	85.7
	Latino or Hispanic	3	8.6
	Prefer Not to Say	1	2.9
	Other/Unknown	1	2.9
Education	Freshman	4	11.4
	Sophomore	11	31.4
	Junior	17	48.6
	Senior	2	5.7
	Other	1	2.9
Major	Mechanical Engineering	31	88.6
	Engineering Plus	3	8.6
	Other	1	2.9

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

Alumni Responses: Survey Demographics

BSU's mechanical engineering alumni were also invited to participate in a separate survey specifically designed for alumni. For the alumni survey, the population was retrieved from the Mechanical Engineering department's comprehensive list. The population of the alumni participants was determined by the database that was created by the Mechanical Engineering department. This database is made up of students who graduated from Boise State University between the years 2000 and 2020, with a total of

928 possible participants. The list does not designate whether the alumni graduated with a BS or MS degrees or both. This list included the alumni's email, first name, last name, LinkedIn/Facebook URL, and graduation date. The alumni participants were selected based on them having taken prior BSU engineering courses and graduating with a BS or MS degree in mechanical engineering. In gathering information based on what they have learned during their time in their industries, we can better understand how BSU has historically addressed this research question.

There was a total of 928 participants that were invited to participate in the survey, yielding 126 responses for a response rate of 11.5%. Table 3.5 shows the gender demographics results of participants that responded. According to Table 3.5, the response rates are 80.2% male, 15.9% female, and 4% prefer not to say. Boise State University has been on a mission to promote diversity and equity specifically in gender and racial inequality. The number of women obtaining engineering roles has risen as can be seen in Tables 3.2, 3.3, and 3.4.

Boise State University has primarily been a Caucasian university; of the 126 responses, about 69.8% were white, with an increase in Latino or Hispanic responses of 10.3%. Throughout the years, BSU has done its part in growing diversity into campus by introducing students to extracurricular events and programs. The growth of Hispanic students at the university has risen due to extracurricular activities directed to multicultural and first-generation students. Tables 3.2, 3.3, and 3.4 identifies the growth of Latino or Hispanic students in the mechanical engineering program.

Based on the responses, the respondents primarily move to the Northwest of the United States for their jobs, with a percentage of 70.6%. There is some slight diversity in respondents moving to other parts of the United States. The age of the respondents varied from 21-45, with some outliers at 46-60+. About 20.6% were in the field of design/development engineering education, 16.7% in production engineering, 15.9% in consulting/professional services, and 11.1% in engineering management. Most of respondents have been employed for 3-20 years.

Table 3.5. Demographics of BSU Alumni in Survey (N=126)

Independent Variable	Group	N	%
Gender	Male	101	80.2
	Female	20	15.9
	Prefer not to say	5	4.0
Age	31-35	30	23.8
	36-45	30	23.8
	26-30	29	23.0
	21-25	20	15.9
	46-50	8	6.3
	Over 60	4	3.2
	56-59	3	2.4
	51-55	2	1.6
Ethnicity	White	88	69.8
	Latino or Hispanic	13	10.3
	Prefer Not to Say	12	9.5
	Other/Unknown	7	5.6
	Black or African American	3	2.4
	Asian	2	1.6
	Native Hawaiian	1	0.8
Location	Northwest U.S.	89	70.6
	West Coast U.S.	10	7.9
	Midwest U.S.	7	5.6
	Outside of the U.S.	7	5.6
	Southwest U.S.	6	4.8
	Southeast U.S.	5	4.0
	Northeast U.S.	2	1.6
Employment Length	3-6 years	32	25.4
	7-10 years	26	20.6
	11-20 years	25	19.8
	Less than 3 years	23	18.3
	Not employed as an engineer (other type of professional)	9	7.1
	Not employed as an engineer (student)	6	4.8
	More than 20 years	5	4.0
Job Function	Design/Development Engineering Education	26	20.6
	Production Engineering	21	16.7
	Consulting/Professional Services	20	15.9
	Engineering Management	14	11.1
	Other	13	10.3
	Research & Development Engineering	10	7.9

	Testing, reliability assurance, quality control	9	7.1
	Student	7	5.6
	General or Corporate Management	3	2.4
	Marketing/Sales	2	1.6
	Education	1	0.8

Based on the results from the alumni survey, there will be a change in how the courses are taught to ensure relevance regarding how the industries are using sustainability. For each semester, sustainability will be taught differently to see the knowledge and attitudes related to sustainability. For each semester and new group of students, they will be asked to participate in the survey. In doing so, we can see the students' knowledge and attitudes towards sustainability based on the ALMs that were provided along with their survey responses. The alumni survey will be distributed once, and those findings will be used to change the ALMs for a new group of students.

Alumni Responses: Interview Demographics

After the distributions for the alumni survey, five survey participants responded with interests in providing more input related to their responses. Participant 1, 2, 3 and 4 responded to the survey and expressed interests in furthering their input in sustainability development. The demographics were found based on the response from the survey. Participant 5 missed the deadline to do the survey but expressed interest in participating in the survey. The demographics (age and ethnicity) found from participant 5 were based on the interview responses. Three of the participants were Caucasian while the other two were Hispanic and African American. All participants were males, and unfortunately there were no female alumni participants that expressed interest. To remain anonymous, each participant was given an alias. The participants varied in age, ethnicity, length of employment, type of job function, and location of job function. These demographics for each participant can be found below.

Table 3.6. Demographics of Interview Participants

	Gender	Ethnicity	Age	Location	Employment Length	Job Function
Participant 1	Male	Latino or Hispanic	26-30	West Coast	Less than 3 years	Research & Development Engineering
Participant 2	Male	Black or African American	31-35	Midwest U.S.	3-6 years	Consulting/Professional Services
Participant 3	Male	White	31-35	Northwest U.S.	7-10 years	Engineering Management
Participant 4	Male	White	31-35	Northwest U.S.	7-10 years	Consulting/Professional Services
Participant 5	Male	White	N/A	N/A	N/A	N/A

Modification of Alumni and Student Survey

The surveys sent out to both alumni and student participants were modified using two past surveys with similar backgrounds. In 2013, a study was conducted on engineers and engineering students; the study indicated that there is a strong focus on implementation on sustainability concepts in education (Rosen, 2013). The survey was sent out to ASME members to determine the attitudes of engineers towards sustainability (Rosen, 2013). This study suggested that many companies are adopting sustainable practices. Because research concluded that industries nationwide and across the globe are adapting more sustainable practices, it is important that instructors bridge the gap between the academic and the professional world (Rosen, 2013). Rosen’s study was conducted to evaluate the attitudes and actions of engineering corporations and practicing engineers (Rosen, 2013). The survey was sent out to ASME members, which was made up of over 120,000 people from over 100 countries in 2009 (*Autodesk/ASME Sustainability Survey Results*, 2009; Rosen, 2013). Approximately 2,100 mechanical engineers and 800 mechanical engineering students responded to the survey to view the sustainability trends practiced in industry and by students (*Autodesk/ASME Sustainability Survey Results*, 2009; Rosen, 2013). Questions from the ASME survey were adopted to the new modified survey to better answer the research questions for this study. The questions included in the modified survey were related to sustainability involvement, confidence level, sustainability interests. The survey was adapted to be used in this study to understand the involvement of students in sustainability practices and alumni perception in sustainability design.

To further understand student's motivation to engage in sustainable practices, Lanziner's survey was used to explore this question (Lanziner, 2018). This quantitative research study focused on undergraduate students who were enrolled in Canadian accredited programs (Lanziner, 2018). 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 where all closed-ended questions were Likert-scaled (Lanziner, 2018). Lanziner's survey used statement-based questions that assess student's motivation by measuring their self-efficiency, or ability to apply these concepts, value, or how students recognize the importance and effects of sustainability, and actions taken based on sustainability concepts (Lanziner, 2018). Results showed that most students were not motivated in sustainable engineering practices, especially the students in mechanical engineering disciplines. Mechanical engineering students are more likely to have more limited experiences in sustainable engineering practices. All students, regardless of background, were biased towards the environmental pillar from the triple bottom line (Lanziner, 2018). It is recommended students have a universal definition of all integrations of the triple bottom line. Although there is a lack of interest in mechanical engineering students, the use of ALMs may increase the interests in sustainability in students. The modified survey used Lanziner's survey to understand alumni and student's belief, attitude, and intention towards sustainability practices. Lanziner's questions were dissected to fit the research questions in the modified survey to better fit BSU students.

The mechanical engineering department at BSU developed a modified survey using The American Society of Mechanical Engineers' (ASME) sustainability study and Lanziner's motivation study (*Autodesk/ASME Sustainability Survey Results*, 2009; Lanziner, 2018). The combination of ASME's and Lanziner's survey will be used to address the research questions. The survey was distributed to engineers and engineering students to identify their attitudes towards the subject. Two versions will be developed, with one tailored for current students and one for alumni.

Purpose of Student Survey

The purpose of this research project is to improve student learning on the concepts of sustainability. The IRB granted approval (Appendix E) to distribute both surveys to the participating sample. The data collected is based on post-survey information from the student sample; this survey will be offered as extra credit at the end of each semester. The student survey consisted of 12 closed-ended and one open-ended questionnaire that reflected on their knowledge, attitudes, and behaviors after being introduced to sustainability (See Appendix A). There are five matrix questions structured as a Likert scale that examine the attitudes and behaviors towards sustainability concepts. The matrix questions used a 5-point Likert scale to measure various sources to referent in a question. This option allows the participant to have various numbers of response alternatives. Questions included basic background questions such as age, ethnicity, major, education level, and gender. Background questions are vital to the research since it is believed that age, gender, and ethnicity play a large role in how students view sustainability topics. The closed-ended question requested students to list courses where they have discussed sustainability. It is believed those who had prior discussion on sustainability in a classroom setting will have a better opinion towards the topic.

Purpose of Alumni Survey

The alumni survey had the same approach as the student survey. The alumni survey was modified using ASME's and Lanziner's survey. This study attempts to understand how to create more engagement in mechanical engineering students by demonstrating how BSU graduates have used sustainability issues in real-world applications. The alumni survey demonstrates the attitude and knowledge of alumni based on sustainability. The alumni survey was slightly longer due to their longer exposure in sustainability designs. The alumni survey consists of 18 closed-ended questions with several matrix questions structured as a Likert scale that examine the attitudes and behaviors towards sustainability concepts. The questions will be based on a matrix question that will discuss their current company's priorities as well as their own. The matrix question used a similar approach as the student survey to include a 5-point

Likert scale to answer a question. Some of these questions examine their beliefs about sustainability and given that sustainability has become a priority for many companies.

Other questions include background questions that will ultimately impact how they respond to the rest of the questions. Basic background questions include information about their gender, ethnicity, age, regional location, employment length and principal job function. The alumni survey will determine which aspects and topics BSU needs to optimize to teach students. The survey designated to alumni participants is found in the Appendix B.

Alumni Interview Questions

For the alumni interview, alumni were asked questions related to their prior experience related to sustainability. Other questions capture their experiences in learning about sustainability at BSU. Some questions include their input on adding sustainability design concepts. While BSU is in the stages of introducing sustainability, every alumni participant did not learn about sustainability in their undergraduate courses, especially since this is a new material being covered in the mechanical engineering program. With sustainability being a new topic, it was important to capture the alumni knowledge related to sustainability as well as the applications they have used in their work field. The responses of these questions will allow BSU to be in a better position to add ALMs based on their experience and what needs to change for future ALMs. The questions below give a good understanding of their comprehension of sustainability:

1. Can you tell me about your experiences learning about sustainability in (Was it in the work field, school or on your own? What stood out to you the most while learning these concepts)?

2. Based on your experiences, what is sustainability?
3. What parts of your (undergraduate education, job training, etc.) were most valuable at developing your understanding of sustainability?
4. What aspects of the BSU ME undergraduate curricula would you have changed to improve your understanding of sustainability?
5. Can you give an example of how you have used sustainability in the past?
6. Is there anything else that you would like us to know about your experiences learning about sustainability?

IRB Protocol

Before performing data analysis on human behavior, the researcher was responsible for completing Collaborative Institutional Training Initiative (CITI) Program courses before obtaining Institutional Review Board (IRB) credentials. CITI Program is dedicated to providing training to individuals for conducting research. Two courses were required to be completed before starting the study. The first course included “Responsible Conduct of Research” which overviews RCR topics that include authorship, collaborative research, conflicts of interest, human subjects, and research misconduct. The second course included “RCR for Social, Behavioral and Education (SBE) Sciences” which describes current information on regulatory and ethical issues that arise when conducting research on human subjects. These courses were required to obtain an IRB approval.

The Institutional Review Board (IRB) is committed to protect the rights and welfare of human subjects that participate in research activities. This project is an addition to *Permeating Resiliency and Sustainability in Undergraduate Engineering* project founded by the National Science Foundation (NSF). While IRB has already approved *Permeating Resiliency and Sustainability in Undergraduate Engineering* project, it was necessary to create a modified version to implement the survey and interview for the students and BSU alumni. IRB approved this study on July 20, 2021. IRB approval can be found in appendix E.

Data Collection

Qualtrics XM is a software that designs and distributes robust digital surveys. Qualtrics XM has grown in popularity due to its high capacity of designing, sending, and analyzing surveys. BSU and many other organizations have used this tool to distribute surveys. Due to the widespread adoption, Qualtrics XM was used to distribute the survey to both the students and alumni participants. Qualtrics XM had the capability to capture the participants who did not complete the survey. The feature allowed users to send reminders to participants to finish the survey.

The quantitative data analysis will use Python to statistically identify the output in demographics in both the alumni and student survey and evaluate the trends on students' knowledge and attitudes from those who were introduced to the modified ALMs. The quantitative data was obtained from pandas, a software library written for python that is mainly used for data analysis and interpretation of data frames. The quantitative data was interpreted through the evaluation of data statistics (i.e., p-value, mean, standard deviation, skewness, and kurtosis) and manipulation of bar diagrams to understand the trends found. To analyze qualitative data, alumni interviews were recorded, transcribed, coded with NVIVO, and assembled into themes addressing industry – sustainability usage from an alumni perspective. By looking at the themes for each semester, we will be able to see the engagement and usage of sustainability. With the practice of sustainability concepts rapidly changing, this data will help analyze the engagement and motivation both students and alumni have over sustainability topics. This information will further be used to incorporate sustainability concepts to the courses by using the horizontal integration method.

Analytical Methods

This study used the demographics to understand the engagement within specific sustainability questions. To determine which dataset are statistically significant, the chi-square distribution (χ^2_{obs}) was used to obtain the p-value as shown in equation (1)

$$p = 1 - P(x < \chi^2_{obs})\ where\ x \sim \chi^2(m - n) \tag{1}$$

where (m-n) is the degree of freedom (expected value) and $P(x < \chi^2_{obs})$ is the probability of $x < \chi^2_{obs}$. The chi-square distribution (χ^2_{obs}) test provides a statistical assessment of the assumptions to find the least squares solution to find the theoretical value (Dahlquist et al., 2015). The theoretical value uses chi-square distribution with ν = m – n, degrees of freedom is then compared to the expected values (Dahlquist et al., 2015). The decision of using chi-square distribution was used to compare the observed results with expected results. Chi-square distribution was used to distinguish the credibility of our sample size.

The dataset is then used to compute the p-value. The p-value must be in-between 0 and 1 to accept the null hypothesis otherwise, we fail to reject the null hypothesis when the p-value equals to 0 or 1. The p-value was viable for distinguishing the credibility of the sample size. The p-value found with chi-square distribution universal code can be found in the appendix (Appendix F). The number of respondents were generally low for the student data causing the p-value found to be out of range from 0 to 1. It was apparent that the demographics were best used if the student data was evaluated with gender, age and ethnicity (i.e., White and Hispanics and or Latinos) demographics. For the alumni data, the p-value for all types of demographics were reasonably ranged to fit 0 to 1.

To further understand the results, machine learning was utilized to obtain the mean, standard deviation, kurtosis, and skewness of each question. Machine learning is an extensive program provided by python to convert variables into numerical values. For this study, the program changed the variables into number and those numbers were determined for the statistical analysis. An example code can be found in the appendix (Appendix G). The results found in this section will not be used to analyze the results but were used to understand the statistical data. The statistical data can be used for future references.

CHAPTER FOUR: RESULTS

Research Question #1 – How do we encourage engineering students' engagement in sustainability to improve learning?

The research question was developed to understand student engagement based on the ALMs that they were exposed to; for this project, engagement is defined as to what extent students are involved with the material based on instructional practices (Yang & Koszalka, 2016). Past research has proven that the increase of student engagement can increase the level of knowledge acquisition and development (Yang & Koszalka, 2016). As noted from multiple studies on the topic of engagement as well as from numerical and anecdotal data from the surveys, increasing student engagement is a worthwhile pursuit, and doing so requires a robust understanding of what students respond to best.

Understanding the results based on demographics can help us improve engineering education; if there are differences in student engagement and exposure to sustainability based on demographics, then that data can be used to design a curriculum that addresses any weak areas. The key demographics used in the student results are related to gender, age, and ethnicity. The alumni demographics results varied from gender, age, ethnicity.

Student Trends for RQ #1

Research question #1 reflects the value a student places on sustainability technologies and concepts, which helps with understanding which methods might be best suited to increase student engagement. Figure 4.1 reflects the Spring 2021 (N=37) students' responses to the survey question "How involved are you with sustainable technologies in your engineering studies?" after being introduces to ALMs. The horizontal axis shows the Likert scale to the survey question. The vertical axis shows the number of respondents in percentages. The p-value for the overall data yielded at 0.03 despite being very low, the datasets showed as statistically significant due to the p-value being between 0 <p-value<1. Less than half of the students were "somewhat involved" (43%) in sustainable technologies, while a few were extremely involved (10%) in sustainable technologies.

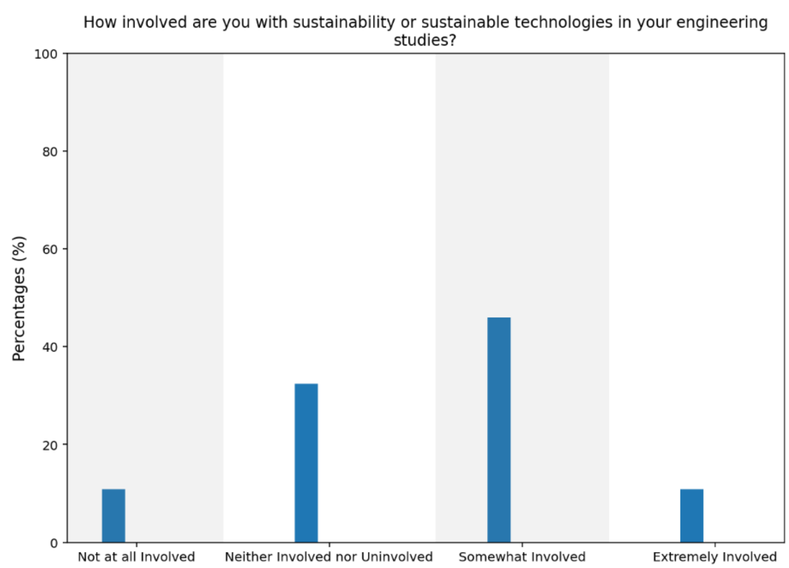


Figure 4.1. Student results for the question "How involved are you with sustainable technologies in your engineering studies?" for Spring 2021

Students from Fall 2021 had slightly different results than those from the Spring 2021 cohort. Based on the pre-survey (N=85) (Figure 4.2), students were neither "involved" nor "uninvolved" in sustainable technologies, with very few who were "somewhat involved". In the post survey (N=35) (Figure 4.3), there is a small increase in students becoming more "somewhat involved" in sustainable technologies. Despite this increase, the results between the pre- (p-value= 0.15) and post-survey (p-value=0.21) stayed consistent.

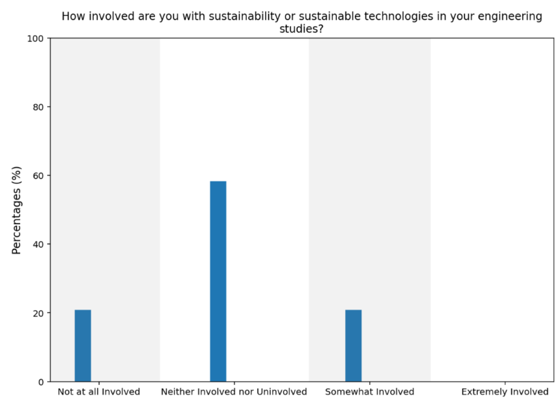


Figure 4.2 Student pre-survey results for the question "How involved are you with sustainable technologies in your engineering studies?" for Fall 2021

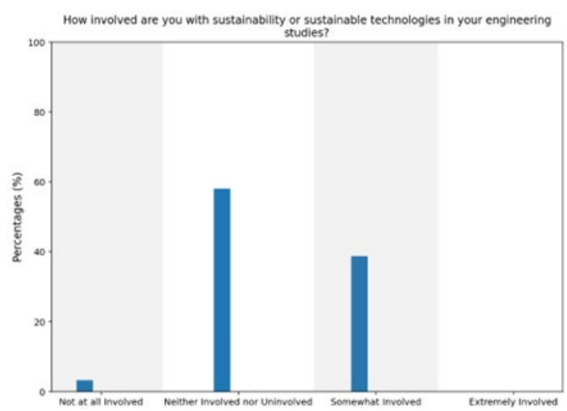


Figure 4.3. Student post-survey results for the question "How involved are you with sustainable technologies in your engineering studies?" for Fall 2021

Figures 4.1, 4.2 and 4.3 evaluate student involvement with sustainable technologies at BSU. A similar survey question was asked to identify a student's involvement outside their engineering studies. Figure 4.4 shows the overall results of the survey question "Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?" The horizontal axis is the Likert scale options for the survey question and the vertical axis represents the percentages of responses. The p-value was found at 0.14 which shows to be statistically significant. For Spring 2021 (N=37) (Figure 4.1), there was a higher percentage of students who were "extremely interested" (20%) in sustainability information compared to those who were involved in sustainability technologies based on their studies as shown in Figure 4.1.

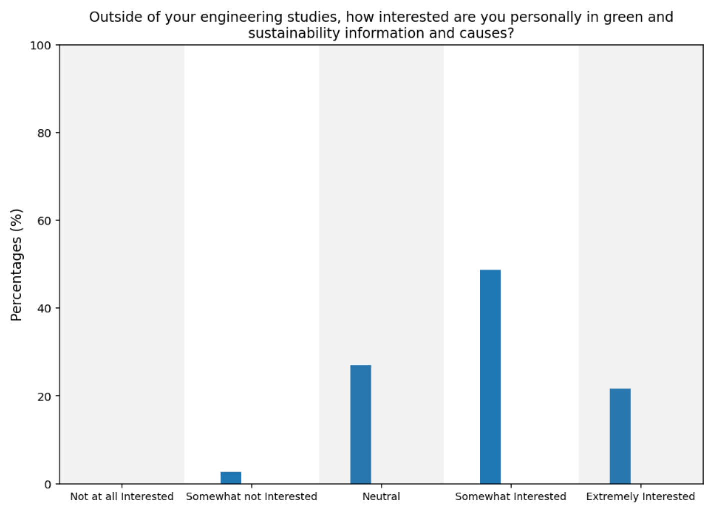


Figure 4.4. Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Spring 2021

Figures 4.5 and 4.6 represent the pre- (p-value= 0.20) and post- (p-value=0.25) data for question "Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?" for Fall 2021. The results from pre- and post-survey show similar trends where the majority of students were 'somewhat interested" in green and sustainability technologies. From the post-survey (Figure 4.6), there is a slight decrease in those who were "extremely interested" (8%) after being introduced to ALMs. It raises questions if the decrease in interest is a result of the low number of participants (N=35) in the post survey is is compared to the pre-survey (N=85).

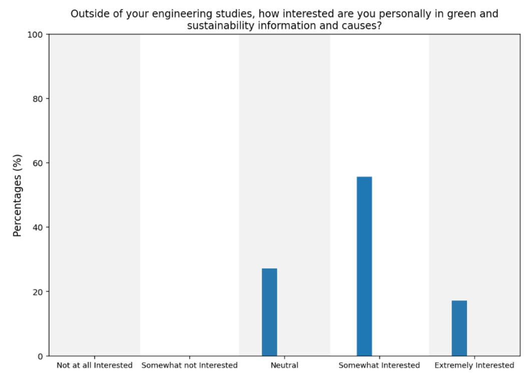


Figure 4.5. Student pre-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021

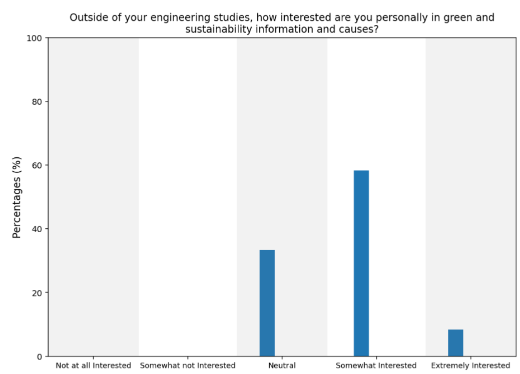


Figure 4.6. Student post-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021

While understanding student involvement and interests based on the data is important, analyzing the student demographics based on sub-groups can help answer the research question with more specificity. While there were five different subsets in demographics, the ones that will be more meaningful for this research questions are: gender, age, and ethnicity. Education level was not selected for close analysis because despite one's education level, these students had little to no exposure to sustainability before ALMs. Major was also not selected because most students are either mechanical engineering or engineering plus majors.

Trend #1: Involvement Based in Gender

The results were further analyzed to observe any differences in responses due to gender. Based on the results, students' have differences in sustainability involvement based on gender. Figure 4.7 represents the post data of students from Spring 2021. The vertical axis represents the percentage of student responses based on the question "How involved are you with sustainability or sustainable technologies in your engineering studies?" The horizontal axis represents the Likert scale types from "extremely involved" to "not at all involved". The male response (p-value = 0.06) gives a confidence level of 94% while the females response (p-value= 0.05) gives a confidence interval of 95%. However, both datasets yield a statistically significant difference due to the p-value being between 0 <p-value<1 thus, causing failure to reject the null hypothesis. Based on the results of Spring 2021 students (N=37), males were more likely to be "somewhat involved" in sustainability technologies at 56%, whereas females averaged 40%. There was a slight increase for females as those who are "extremely involved".

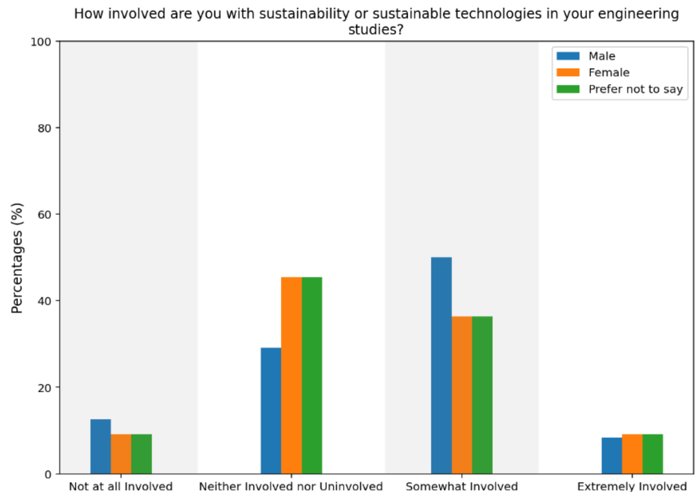


Figure 4.1. Student results for the question "How involved are you with sustainable technologies in your engineering studies?" for Spring 2021 based on gender

Figure 4.8 and 4.9 represent the pre- and post- data for students from Fall 2021. The horizontal axis represents the four Likert scale options provided from the question while the vertical axis is the percentage of student's responses. With different ALMs presented in Fall 2021, involvement based on gender differs from Spring 2021. For the pre-survey, the male response yielded at a p-value = 0.11, female response yielded at p-value= 0.24 and prefer not to say yielded at p-value = 0.42. However, both datasets had a statistically significant difference due to the p-value being between 0 <p-value<1 thus, accepting null. From the pre-survey data (N=85) (Figure 4.8), females and "prefer not to say" respondents were neither involved nor uninvolved at 70%, while males were at an average of 58%. The pre-survey data shows that males were about 20% were "somewhat involved" in sustainability.

The post data (N=35) (Figure 4.9) shows a different trend. Females and "prefer not to say" increased in exposure to sustainability technologies by 40%. For males (p-value = 0.21), the increase in sustainability engagement increased as well, but females (p-value = 0.22) and “prefer not to say” (p-value = 0.42) increased at a slightly higher percentage. All datasets lie between 0 <p-value<1 so the data shows to be significant. In the post survey, all subsets increased in involvement by more than 40%. Of note, the increase shown by females is 10% more than men.

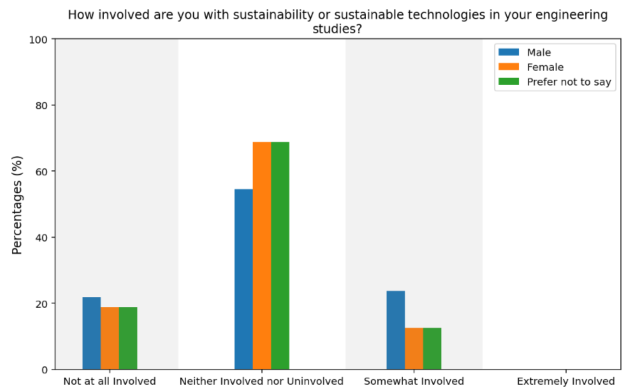


Figure 4.8. Student pre-survey results for the question “How involved are you with sustainable technologies in your engineering studies?” for Fall 2021

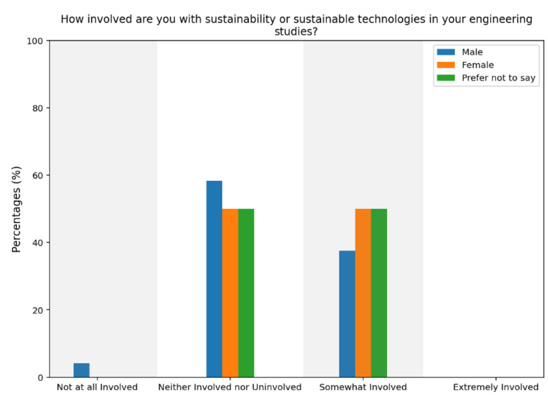


Figure 4.9. Student post-survey results for the question “How involved are you with sustainable technologies in your engineering studies?” for Fall 2021

More notable trends were found on those students who are interested in green and sustainable technologies outside of their studies. Figure 4.10 displays the survey question “Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?” for Spring 2021 based on gender. From the post data (N=37) (Figure 4.10), about 28% of women (p-value = 0.20) were listed as extremely interested in sustainability while men were about 18% extremely interested. Females were also somewhat more interested in sustainability at 58%, while the men (p-value = 0.28) were about 55%. “Prefer not to say” (p-value = 0.15) respondents were equally divided by either neutral or extremely interested.

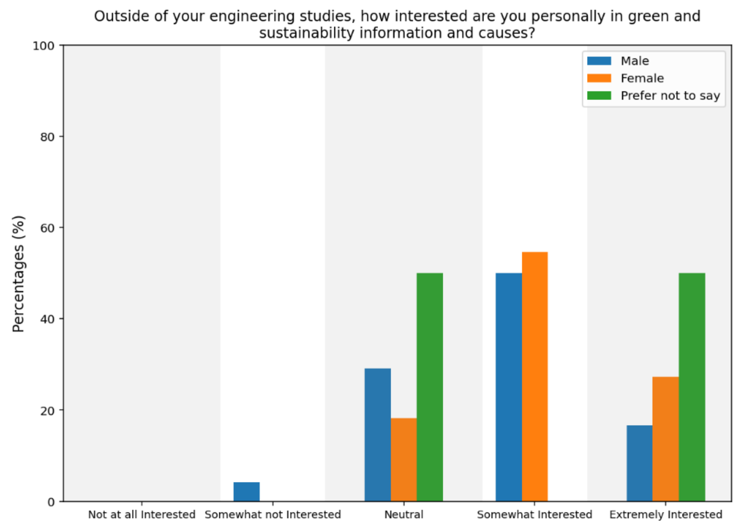


Figure 4.2. Student results for the question “Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?” for Spring 2021 based on gender

In comparison to Spring 2021, females were more interested in sustainability than males. From the pre- (N=85) and post- (N=35) survey, the results were consistent and there was no noticeable difference between the pre and post data. In both pre and post data, most women were extremely interested in sustainability technologies compared to male respondents. After the introduction of ALMs, there was an increase in women's (p-value=0.18) interests from the “somewhat interested” column by 15%. The data for the males stayed consistent with being slightly interested in green technology.

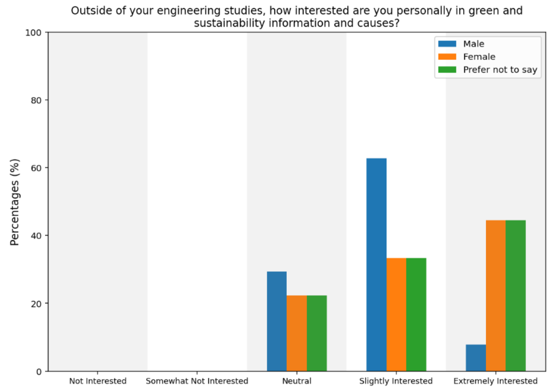


Figure 4.11. Student pre-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on gender

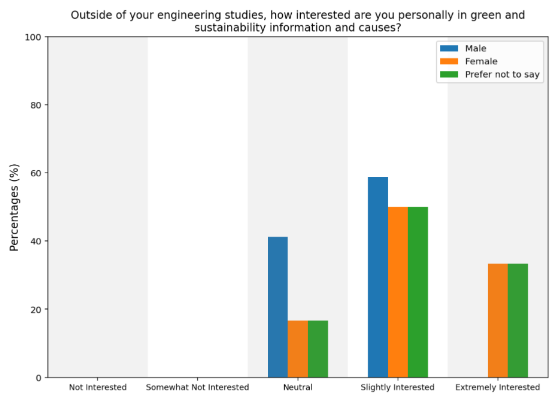


Figure 4.12. Student post-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on gender

Trend #2: Involvement based on Age

Sustainability is a growing subject that has been around less than 40 years but has grown more in popularity in the last 20 years. As such, it's no surprise that age plays an important role in understanding sustainability technologies. Age can change a person's perspective on sustainable technologies since it is more likely for someone to learn about sustainability when they are younger (in their undergraduate studies, for example). Figure 4.13 represents the survey question to "How involved are you with sustainability or sustainable technologies in your engineering studies?", which is dissected into a subset of ages for Spring 2021 students (N=37). The horizontal axis along with the gray-and-white shaded areas represents the Likert scale to the question. The vertical axis represents the percentages of respondents. Ages 31-35 (p-value = 0.02) are evenly distributed from “not at all involved”, “neither involved nor uninvolved” and “somewhat involved”. Ages 18-20 (p-value=0.07), 21-25 (p-value=0.29), and 26-30 (p-value=0.27) gradually increased in interest levels. It apparent that students with the ages of 26-30 were extremely interested in sustainable technologies. Due to the limitation of diversity in age for students, there were no observed trends in engagement for this cohort. All dataset shows to be statistically significant due to the p-value lying between 0<p-value<1.

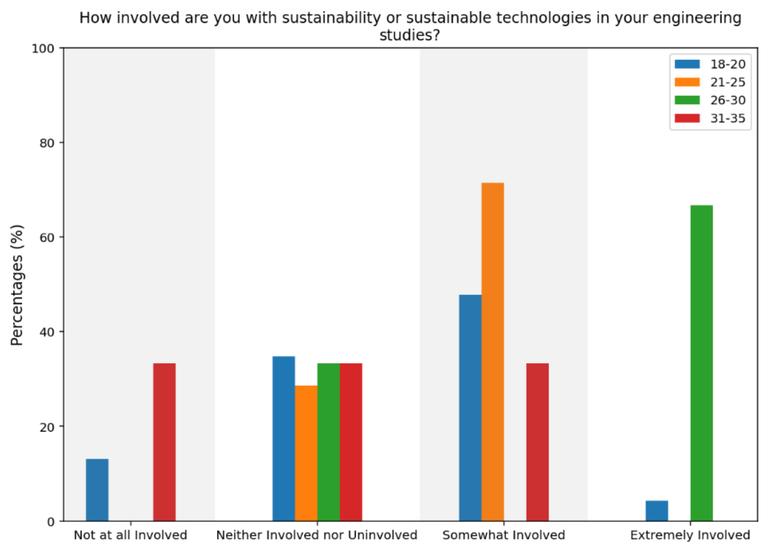


Figure 4.3. Student results for the question “How involved are you with sustainable technologies in your engineering studies?” for Spring 2021 based on age

Figures 4.14 and 4.15 represent the same survey question but with the Fall 2021 students. Figure 4.14 shows the pre-survey data (N=85) and Figure 4.15 shows the post-survey data (N=35). The Fall 2021 students had more diversity in age, as student’s ages varied from 18-40. Before being introduced to ALMs, the majority of students responded as “neither involved nor uninvolved”. All respondents from ages 31-35 responded as “not involved at all” in sustainability technologies and those who were 36-40 years old responded as “somewhat interested” in sustainable technologies. After being introduced to ALMs, the data frame changed for all ages except those who were 36-40 years (p-value=0.42) of age. There was an increase in sustainable technologies exposure in all ages specifically in those who are 31-35 (p-value=0.22).

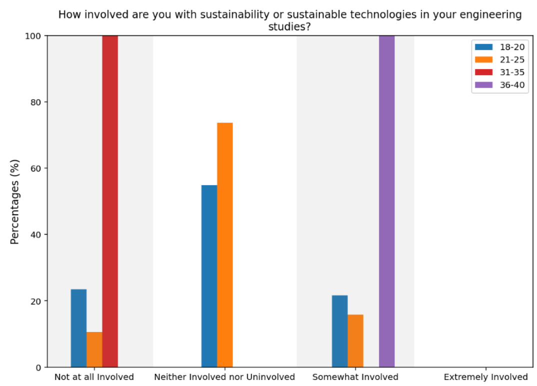


Figure 4.14. Student pre-survey results for the question “How involved are you with sustainable technologies in your engineering studies?” for Fall 2021 based on age

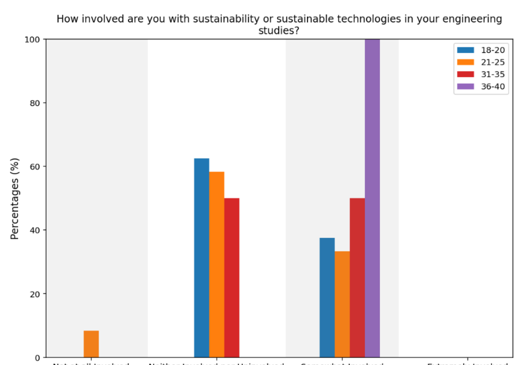


Figure 4.15. Student post-survey results for the question “How involved are you with sustainable technologies in your engineering studies?” for Fall 2021 based on age

When surveyed by age, there was a noticeable difference in interests outside of the respondents’ studies. Figures 4.16, 4.17 and 4.18 below are the responses to the survey question “Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?” divided by different ethnicity groups for Spring 2021 (N=37). The older the student was, the more interested they were about sustainability. Ages 26-30 (p-value=0.31) and 31-35 (p-value=0.10) were significantly more interested than younger respondents. Younger respondents typically fell in the category of "somewhat interested" regarding sustainable technologies.

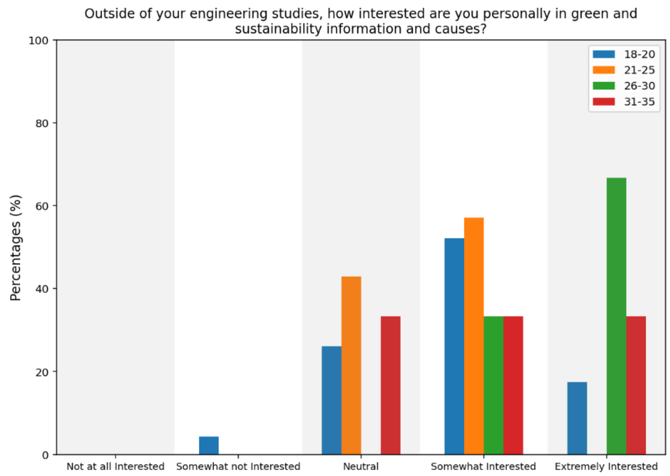


Figure 4.4. Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Spring 2021 based on age

For students in Fall 2021, the trend changes from the students of Spring 2021. There were less older students in this cohort which caused the groups data to be scattered in those who are older. Generally, those who are ages 18-20 and 22-25 stayed consistent. The younger generation generally were slightly interested in sustainable technologies. Despite the lack of diversity, all p-value fell in the range of 0 and 1 making the data sets for the pre- and post- survey to be statistically significant. The p-values for the dataset can be seen in Appendix H.

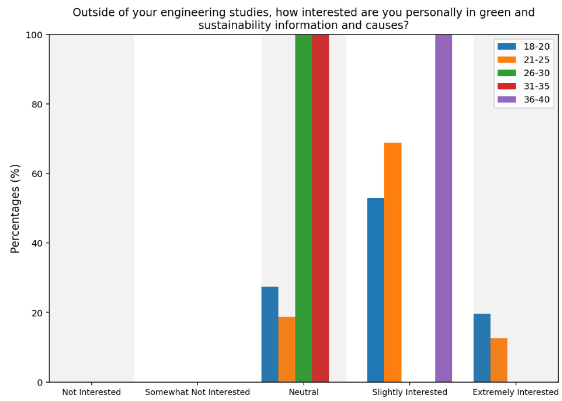


Figure 4.17. Student pre-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on age

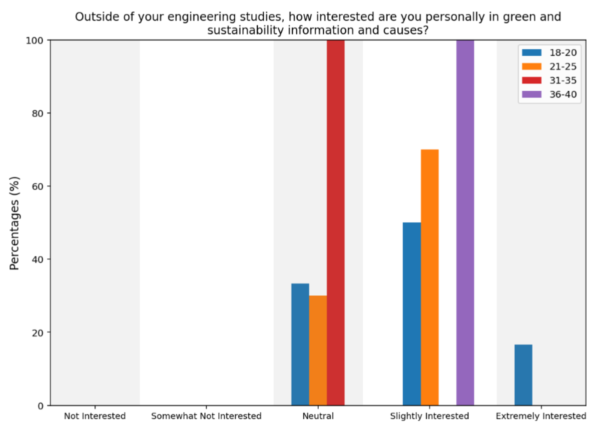


Figure 4.18. Student post-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on age

<u>Trend #3: Involvement based on Ethnicity</u>

With BSU being prominently a Caucasian university, BSU has taken strides to become a more diverse university. Ethnicity was considered for this study to better assist a range of students. The figure below (Figure 4.19) deconstructs the research question "How involved are you with sustainable technologies" based on ethnicity subgroups for Spring 2021 (N=37). The white (p-value= 0.05) and Latino (p-value=0.42) respondents leaned more neutral in sustainable technologies. The Asian population (p-value=0.42) were split evenly in their involvement in sustainable technologies.

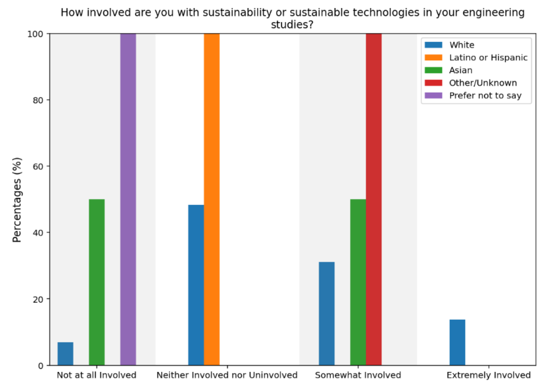


Figure 4.5. Student results for the question "How involved are you with sustainable technologies in your engineering studies?" for Fall 2021

In Fall 2021, there weren't any Asian participants for this study and the only diversity group was "Latino or Hispanic." There was more variation in this cohort than in Spring 2021. As shown in the pre-survey data (N=35), Latinos are likely to be more involved in sustainable technologies than the White subgroup. After the introduction of ALMS, the White group increased in involvement by about 20%. There is also an increase in Latino involvement by 15%. All p-values were in range from 0 to 1 thus, causing failure to reject the null.

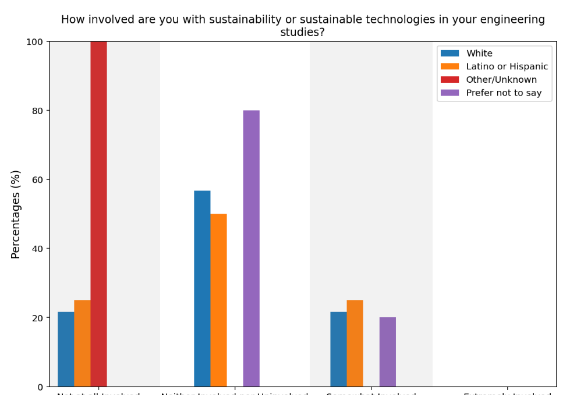


Figure 4.20. Student pre-survey results for the question "How involved are you with sustainable technologies in your engineering studies?" for Fall 2021 based on ethnicity

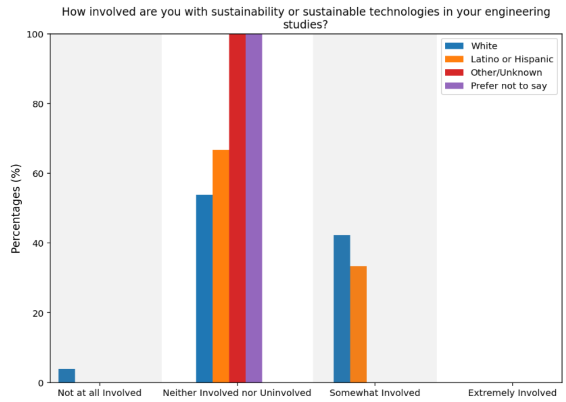


Figure 4.21. Student post-survey results for the question "How involved are you with sustainable technologies in your engineering studies?" for Fall 2021 based on ethnicity

As a way to grasp respondents' interests in sustainability even further, Figures 4.22, 4.23 and 4.24, shows data regarding the question of "Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?" varied by ethnicity. Based on Figure 4.19 and Figure 4.22, all ethnicities were interested in sustainability technologies despite not being involved in sustainability. Specifically in Latinos (p-value=0.31) about 65% of respondents were somewhat interested in sustainability while the white subgroup (p-value=0.13) was somewhat interested in sustainability by about 70%. The Asian population (p-value=0.28) as interested split equally between neutral and extremely interested.

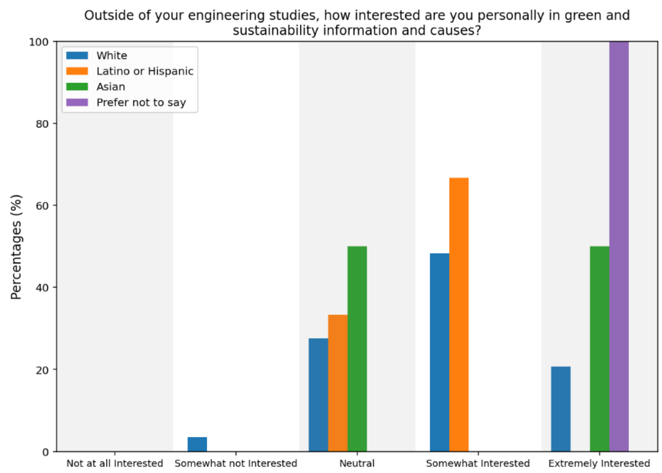


Figure 4.6. Student results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Spring 2021 based on ethnicity

The Fall 2021 cohort had similar trends as Spring 2021. Figures 4.20 and 4.21, show that students were not involved in sustainability technologies in their studies but Figures 4.23 and 4.24 show that they are very interested in learning about sustainability. This is directly seen in Latinos and/or Hispanics. After the introduction of ALMs, Latino and Hispanic (p-value=0.28) students grew more interested by about 40%. Even before the introduction of ALMs, Latinos and Hispanics (p-value=0.23) participants responded as "extremely interested" in sustainability slightly more than White students (p-value=0.23).

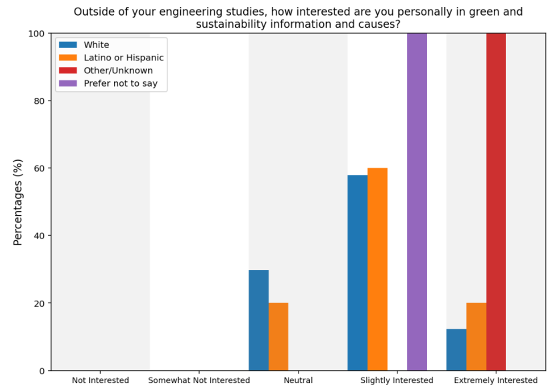


Figure 4.23. Student pre-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on ethnicity

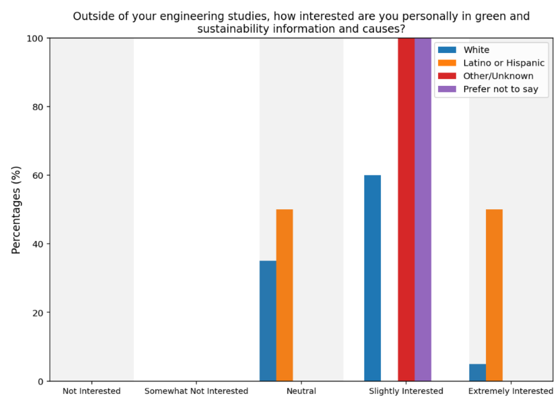


Figure 4.24. Student post-survey results for the question "Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?" for Fall 2021 based on ethnicity

<u>Alumni Trends for RQ #1</u>

Most alumni had a different classroom setting when doing their undergraduate degree at BSU. Alumni before 2020 had little to no coverage on sustainable development. When looking at the overall trends from the whole dataset, it's apparent that most of the alumni have been very interested in learning about sustainable technologies. As shown in the figure below (N=126) (Figure 4.25), the majority were currently interested in sustainability studies. The overall data (p-value = 0.15) gives a confidence level of 85% and has shown to be statistically significant.

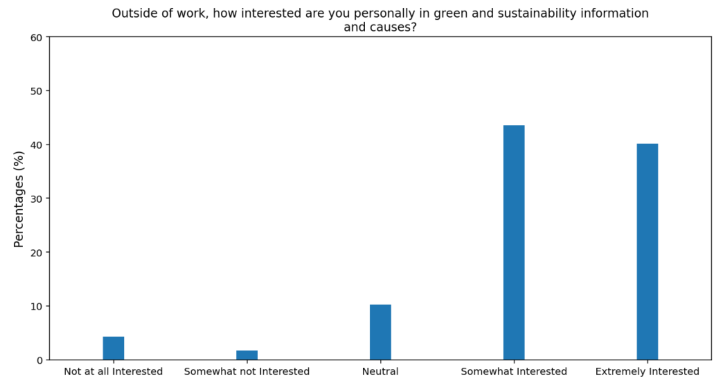


Figure 4.7. Alumni results for the question "Outside of work, how interested are you personally in green and sustainability information and causes?"

Despite respondents' interests in sustainability, their confident levels in applying sustainability were rather low. More than half of alumni respondents were moderately to not confident in applying sustainability design concepts into their work projects. Only about 5% could agree that they are "extremely confident" and 8% are "very confident" in applying sustainability into their design concepts. The p-value is yielded at 0.02 which results a confidence level of 98% and has shown to be statistically significant.

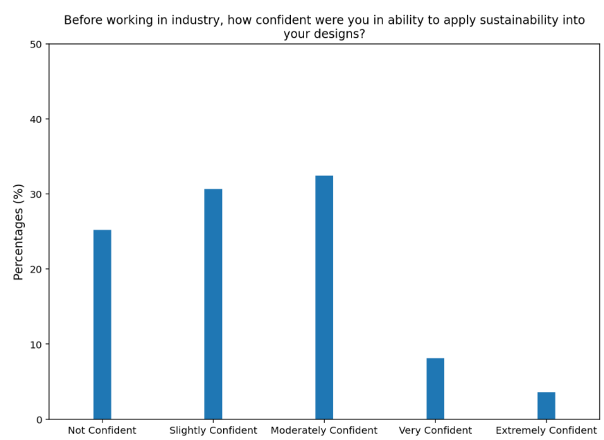


Figure 4.8. Alumni results for the question "Before working in industry, how confident were you in ability to apply sustainability into your designs?"

This trend shows a very clear drop off after "moderately confident", which can be addressed in future curriculum development to ensure students can confidently apply sustainable practices and development into their careers. Because research question #1 heavily focuses on the engagement students have towards sustainability, it is good practice to consider the student demographics when considering future curriculum development. As noted, the key demographics were age, gender, and ethnicity.

Trend #1: Confidence Levels in Gender

From survey data (N=126), it was apparent that most alumni were not taught about sustainability in their undergraduate studies. Most of their exposure to sustainability was inherited through work and through their own involvement. Despite the lack of exposure, most of the alumni participants regardless of gender were very interested in green and sustainable information and causes. Figure 4.27 displays the alumni results based on gender for the question “Outside of work, how interested are you personally in green and sustainability information and causes?” The horizontal axis shows the Likert scale for responses. The vertical axis illustrates the percentage of response based on gender. “Prefer not to say” respondents were not included in the figure due to the low response rate of 4%. The p-value for the female’s results was 0.07 creating a confidence level of 93%. Both the female and the male (p-value=0.15) responses were in the range of 0 and 1 which shows the significance of the results. Based on Figure 4.27, about 58% of females were extremely interested in sustainability information and causes, whereas men were about 40% extremely interested, creating a difference of 18%. Interest levels from women respondents rose noticeably, while interest levels in men seemed to drop.

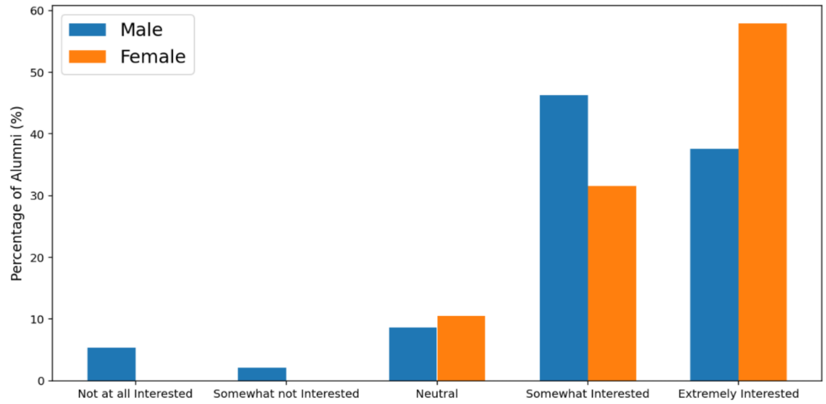


Figure 4.9. Alumni results for the question "Outside of work, how interested are you personally in green and sustainability information and causes?"

Before working in the industry, some alumni recalled feeling a lack of confidence in applying sustainability into their design work. Figure 4.28 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. 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 (p-value =0.04) tends to be "moderately confident" or "somewhat confident" with applying sustainability into their designs. It noted that 50% of women (p-value =0.11) reported being "not confident" in applying sustainability, and only 12% of women reported being "very confident". A similar trend can be found in the male's results; a majority of male respondents (35%) felt that they were "moderately confident", with 4% who responded with "extremely confident". Because the alumni participants had little to no coverage of sustainability concepts during their undergraduate career, it is assumed that this directly affected their confidence levels in applying sustainable practices in their work.

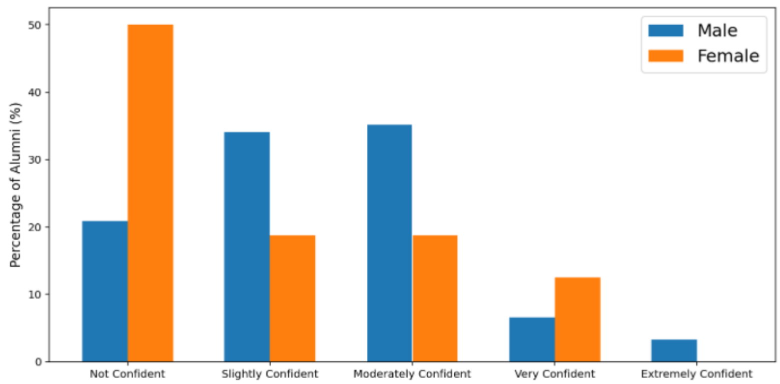


Figure 4.10. Alumni results for the question "Before working in industry, how confident were you in ability to apply sustainability into your design?"

Figure 4.27 indicate a slight contradiction in results due to a high level of interests in sustainability but low confidence in the application of sustainability in their engineering work. The confidence level is more noticeable when looking at the women's responses. Based on studies on psychological differences between gender, the interest levels in women tends to be higher (Meinzen-Dick et al., 2014). The confidence level in sustainability and engineering can also be partially attributed to womens' sense of belonging in engineering firms (Clark et al., n.d.) thus, showing the low confidence in Figure 4.28.

Despite these differences in male and female responses, it was clear that most alumni did not have confidence in applying sustainability into their design work regardless of gender. However, to increases the confidence specifically in women, there must be an a more structured way of presenting sustainability into the curriculum while making women feel included in the design principles. The students in Spring 2021 experienced ALMs such as a female guest speaker who spoke about their personal experience with sustainable development. When compared to Fall 2021 students, where students were introduced to BSU sustainable development, female students from Spring 2021 showed more engagement with sustainability.

Trend #2: Younger Generation growing Appreciation on Sustainability

With sustainability becoming an increasingly popular topic, different age groups have been perceiving sustainability differently based on their own experiences. In this demographic, data shows that different age groups are more interested on sustainability based on how much exposure to sustainability they receive.

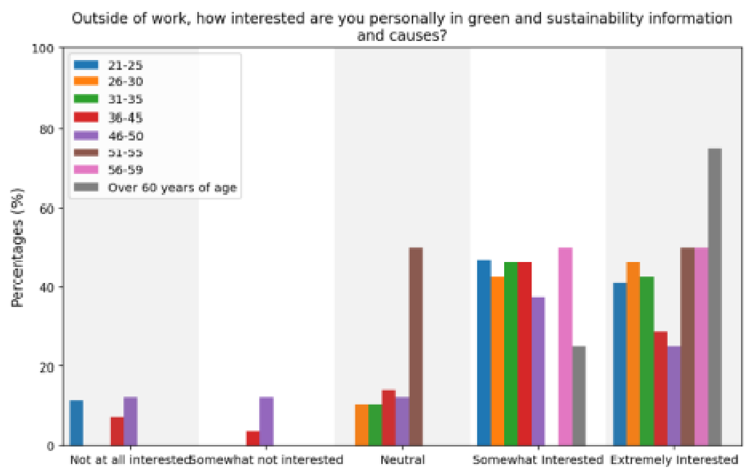


Figure 4.11 Shows the alumni data results to question "Outside of work, how interested are you personally in green and sustainability information and causes?" based on different age groups.

As shown below about all age groups are extremely interested with some type of sustainability information and causes. Those who are middle aged (36-45 and 46-50) were the least interested in sustainable information and causes. Despite the low interests in sustainability, there is a growth in the younger generation.

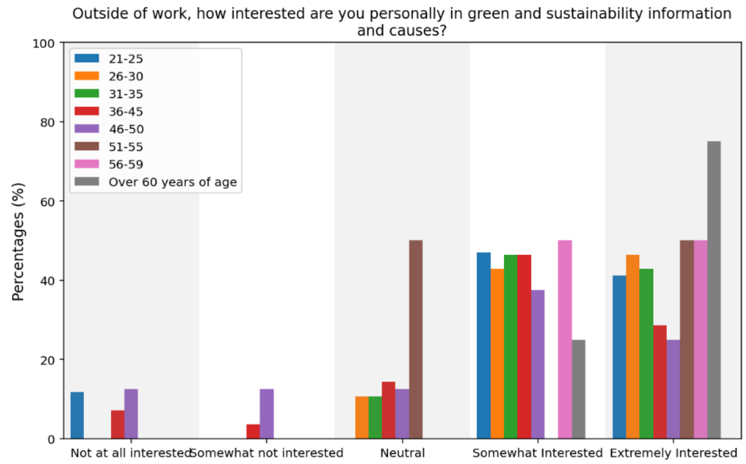


Figure 4.12 Alumni results for the question “Outside of work, how interested are you personally in green and sustainability information and causes?” based on Age

Mostly every age group had little to no confidence in the application of sustainability in their design concepts prior to working in an engineering position. Only about 10% middle aged respondents (31-35 and 36-45) identified themselves as being “extremely confident” in applying sustainability into their engineering work. It’s important to note that their confidence levels were low post-graduation, their current confidence levels were not evaluated for this study. The majority agreed that they were “moderately confident” in applying sustainability into their designs. Those who were ages 46-50 (p-value =0.12) majority agreed (50%) that they were not confident in applying sustainability. All the p-values for these questions fit in the range of 0 and 1 thus, failure to reject null.

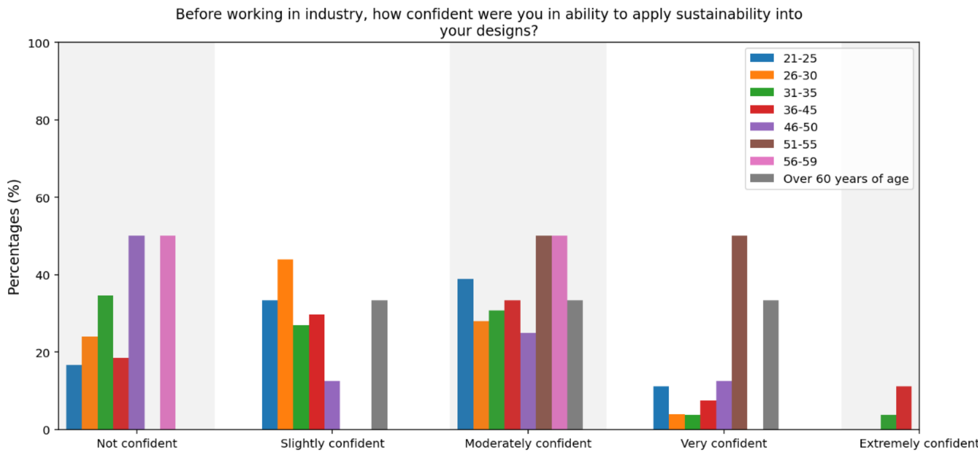


Figure 4.13. Alumni results for the question "Before working in industry, how confident were you in ability to apply sustainability into your design?" based on Age

Trend #3: Ethnicity on Sustainability

The alumni data set had a better range of diversity than the student data. Looking at ethnicity in the alumni data is crucial to identify which ethnicity values sustainability in their designs. The figure below (Figure 36) identifies the survey question of "Outside of work, how interested are you personally in green and sustainability information and causes?" sectioned by ethnicity. While Latinos or Hispanics (p-value =0.16) follow the same pattern as White (p-value =0.16) respondents, Latinos show a higher percentage in interests for sustainable information and causes. This same trend follows for Black and African American respondents (p-value =0.31), with 65% being "extremely interested" in sustainability. From all the ethnicity groups, Latino or Hispanic are extremely involved while they yield at 64%.

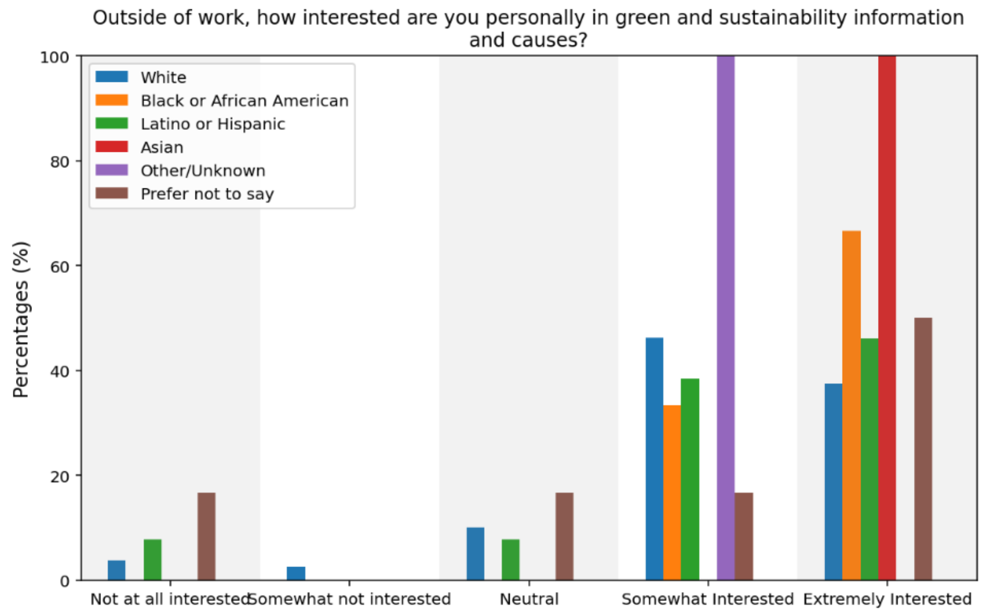


Figure 4.14. Alumni results for the question "Outside of work, how interested are you personally in green and sustainability information and causes?" based on Ethnicity

When looking at their confidence levels by ethnicity, all groups lose their confidence in applying sustainability into their design work. While most of the respondents are required to apply sustainability into their work as shown in Figure 4.33, most alumni are moderately or less confident. This confidence level is visible in White (p-value =0.02) and Asian (p-value =0.28) respondents. About 39% of White respondents were "slightly confident", and 34% acknowledged they were "not confident" at all. Latinos or Hispanics (p-value =0.18) and Black or African American (p-value =0.44) respondents were more moderately confident in applying sustainability. Based on Figure 4.33, this confidence level can come from their higher involvement with sustainability technologies from their organizations. Despite White respondents' involvement with sustainability, they are aware that they lack in confidence in applying sustainability, as most were slightly to not confident. "Prefer not to say" (p-value =0) results can be neglected due to the p-value not fitting the range of 0 to 1, thus rejecting the hypothesis. Despite this, this does not mean that the alternative data is false.

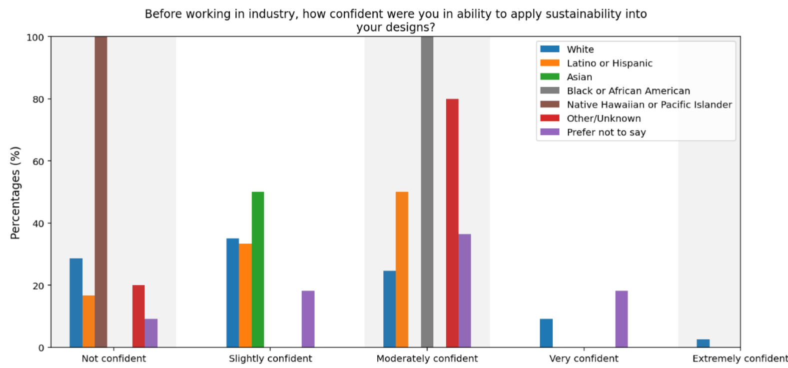


Figure 4.15. Alumni results for the question "Before working in industry, how confident were you in ability to apply sustainability into your design?" based on Ethnicity

<u>Alumni Interview Input for RQ #1</u>

<u>Trend #1: Alumni Exposure in Sustainability at BSU</u>

To further analyze this research question in depth, it was important to recognize the beliefs and the learning outcomes of sustainability. BSU alumni who participated in the study emphasized the different perspectives on their knowledge of sustainability granted from BSU. Most of the participants in the study struggled defining sustainability. A majority of the alumni participants recall the lack of sustainability their curriculum added to their courses and a few participants believed it shaped their perspective on sustainability. Participant 1 had little to no coverage of sustainability and expressed their lack of interest in sustainability. He believed that sustainability is just a public image word that companies enforce to increase its consumers' interests.

> "Companies try to shove it down your throat. Trying to make everything green, from learning about carbon taxes and wanting to make everyone go vegan. That aspect kind of throws me off, I would be more interested if

> people [companies] weren't trying to enforce it on you. It can be beneficial for the user and for the company that advise it … I never learned about this in college so maybe that might affect my opinions on this."

Participants 1 acknowledges the increase in advertisement towards sustainability however, he admits that the lack of exposure in his undergraduate studies shaped his way of thinking. When asked where he learned about sustainability, he replied:

> "ENGR 120 and that's the only time I can remember hearing about it in a class… A BSU professor was teaching a renewable energy course and I had a friend who worked in a renewable energy lab at BSU, and I think they would go to different [energy-related] facility but I was not involved in that."

Without the introduction of sustainability and proper guidance on learning how to apply sustainability, participant 1 struggled to understand the importance of sustainability. After graduating BSU, he didn't comprehend the reasoning sustainability is heavily applied in different organizations

Participant 2 had a different perspective about sustainability. Participant 2 assisted in different sustainability projects outside of class which shaped their perspective about sustainability overall.

> "So, initially, I started learning about sustainability when I was at school, Boise State University. And I think, when I was involved in the industrial Assessment Center was really when I became interested, shaped my thinking, got introduced to sustainability related to engineering. Then after

> that. I don't think I took any renewable energy courses at Boise State. So, I just got into the field by doing energy efficiency consulting, but then found the field of sustainability and my interest kept growing… like climate change and government policies are kind of accelerating the consciousness particularly with sustainability, people, how we use things, how they are manufactured and their carbon footprint and things like that, so I learned a lot from working in the field."

Participant 2 was introduced to sustainability with BSU's Industrial Assessment Center (BS-IAC) which helps small industrial facilities to obtain free energy, productivity, and waste assessment. Unfortunately, BSU is no longer an active IAC center. With this program, Participant 2 was able to build a career by applying sustainability into their design work and using real life examples. Participant 2 was the only person who was able to define sustainability in relation to the triple bottom line. When asked what sustainability is, he responded with,

> "Ah, I would say, engineering and manufacturing practices that involve less impact to the environment, or environment health, safety of people and wildlife. So, practices that decrease the negative impact to the environment and, and people and in wildlife."

Despites the differences between these responses, it should be noted that these perspectives were framed in part due to their life experiences. Participant 1 went into the field of manufacturing while participant 2 worked in the field of sustainability. Participant 1 was briefly introduced to it during a now inactive course ENGR 120 but without the repetition of sustainability in his courses, he struggled to hold his engagement in sustainability.

Trend #2: Alumni Recommendations

In the interview, alumni participants were asked to answer, “What aspects of the BSU ME undergraduate curricula would you have changed to improve your understanding of sustainability?”. This question was asked directly to see what changes they would have like to see for the upcoming students. Participant 4 has worked in the commercial grade refrigeration and has used sustainability in different projects.

> “I specifically remembering learning about stream systems and refrigeration systems in thermodynamics. We learned about the different types of cycle, and we spent a few days learning about how to recover some energy. I think it would be great if students would spend more time on reduction of energy problems and providing students with more examples on how to recover energy.”

This participant in particular went on to talk about the courses that are already in class and to add more sustainability examples in class. Often reduction in energy related examples is neglected and he would have enjoyed seeing that more in the classroom especially in upper-level courses. Participant 5 had a similar response.

> “It didn't exist when I was when I was doing my undergraduate. In the early 2000s, there wasn't a component of the program to instill sustainability although, I could see a couple opportunities where it could easily be integrated. I think a course like thermal systems design where

you're dealing up with HVAC systems and calculating the energy flows would be a great way to start. Also including the economic impacts or the sustainability impacts that are applied to these systems"

Participant 5 went to BSU in the early 90's so sustainability was rarely talked about or even introduces in courses. It's unknown if this participant did additional schooling after their undergraduate degree. Despite not learning about sustainability, this participant was able to learn about it through school and understand the importance of sustainability. As participant 3, he would have liked to see more sustainability related problems in upper-level courses.

These participants understand that there should be an addition to adding sustainability into courses that deal with energy which are typically upper-level courses. They don't specify that this can increase engagement, it may be able too. Students learning about sustainability in ways that relate to their major can increase their interests regarding sustainability.

Research Question #2 – Are the sustainability topics used in ALMs relevant to industry applications for mechanical engineering?

To improve ALMs, it is important to understand the current sustainability practices in the engineering industries. Research question #2 aimed to gather data about BSU alumni experiences in their work environments since their undergraduate studies. This data will allow BSU to be in a better position to implement sustainability examples that can better suit students. Research Question #2 can assist students, professors at BSU and the Mechanical and Biomedical Engineering Department in furthering the goal in adding sustainability concepts to the curriculum.

Before analyzing the sustainable work done by alumni, it is important to analyze a student's perspective of importance in sustainable technologies. Understanding their connection with sustainable industry application can help with understanding their views and attitudes with sustainability.

Student Trends for RQ #2

Trend #1: Students Connection with Sustainable Industry Application

Introductory courses are a good way to give freshman and sophomore students the basics of sustainability, but without examples of real-life applications, students will struggle to understand the use of sustainability technologies within their industries. In addition, because introductory courses are typically in the beginning of a student's undergraduate career, they have to learn both engineering fundamentals and sustainability, which means ALMs are even more necessary to encourage student retention of the material.

When students were asked their opinion on the importance of sustainability technologies, they based their opinion on their perspective on sustainability technologies shown in their courses. Students were asked "Which of the following sustainable technologies do you consider to be the most important?" based on the questions below 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

Each bar graph represents a different question that is then used as a 5-point Likert scale of which participants rate to which they identify the importance from the question listed above. Question 9 was not shown due to the low responses. The student participants were able to insert other viable options that they may consider important for sustainability technologies. Examples included products that use the life cycle sustainability assessment, longevity in product design such as durability or re-usable products, nuclear energy and minimizing electricity. The least of importance included packaging and products that require less packaging (27%). The most important technology for this cohort was the manufacturing processes that use less energy and natural resources (56.7%).

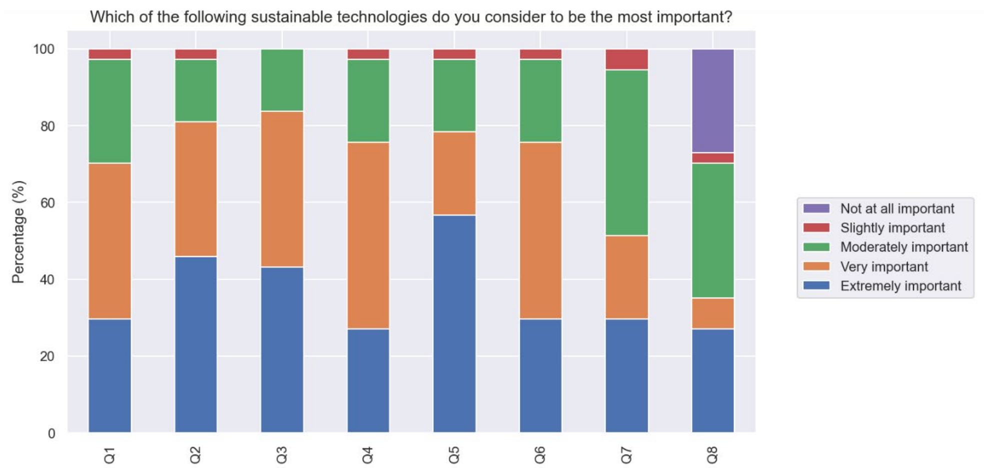


Figure 4.16. Spring 2021 Student Response Post Data for question "Which of the following sustainable technologies do you consider to be the most important?"

Students in Fall 2021 were presented different ALMs but were given the same survey for the pre- and post- data set. The same trend did not follow for the Fall 2021 cohort. Between the pre- and post- data, the results varied for the most important sustainability technologies. For the pre-survey, results were similar as the students from Spring 2021. Figure 4.35 shows that most students believe that manufacturing processes that use less energy and natural resources is an important aspect when applying sustainability. They were also given the choice of writing other options. Examples included longer use of products, safe work environments and minimizing waste. A few mentioned that all technologies are considered very important.

Figure 4.36 represents the post data to the question "Which of the following sustainable technologies do you consider to be the most important?" There is a difference between the pre- and post- data. The post data shows that students believe that designs that use renewable/recyclable/recycled materials are considered to be extremely important alongside designs with manufacturing processes that produce less pollution and greenhouse gasses. Between all the cohorts and the pre- and post- results, they all agreed that products that require less packaging are the least important technologies.

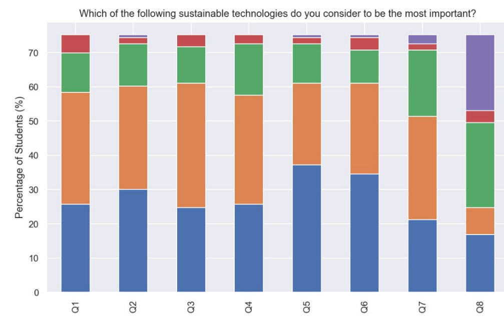


Figure 4.35. Fall 2021 Pre-Data for Student Response for question Which of the following sustainable technologies do you consider to be the most important?”

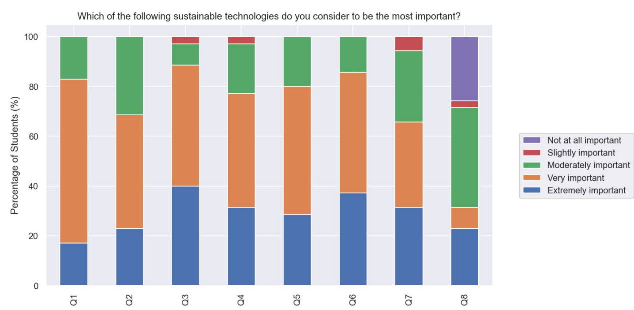


Figure 4.36. Fall 2021 Post Data for Student Response for question Which of the following sustainable technologies do you consider to be the most important?”

The results for all cohorts vary due to students lacking experience with industry applications. The only exposure students received were during lectures integrating ALMs. The difference in number of respondents per semester and pre- and post- survey fluctuates the data.

Alumni Trends for RQ #2

Trend #1: Alumni Involvement in Sustainability

Alumni have seen a certain growth in sustainability applications correspondence to their work field. With sustainability on the rise, many companies are beginning to advocate for environmental regulation, environmentally friendly packaging, and LEED certified building. BSU has seen this same growth in the companies they work with. To further analyze research question #2, it is important to understand alumni's opinion in sustainable technologies based on their personal experiences. Figure 4.37 displays the bar graph that is related to the question, "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 gasses

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

Q8: Products that require less packaging

Q9: Other

Each bar graph represents a different question that is then used as a 5-point Likert scale of which participants rate to which they identify the importance from the question listed above. Alumni participants considered designs that comply with environmental standard and regulation (41%) to be the most important sustainable technologies. The least important were designs that use renewable/recyclable/recycled materials (7.4%) and products that require less packaging (5.5%), which contradicts the student's post-survey results (Figure 4.34 and Figure 4.36). Students were able to recognize that environmental standards and regulation must be followed to meet governmental approval. In relation to importance, students believe that to be sustainable, designs should try to be using more renewable/recyclable/recycled materials.

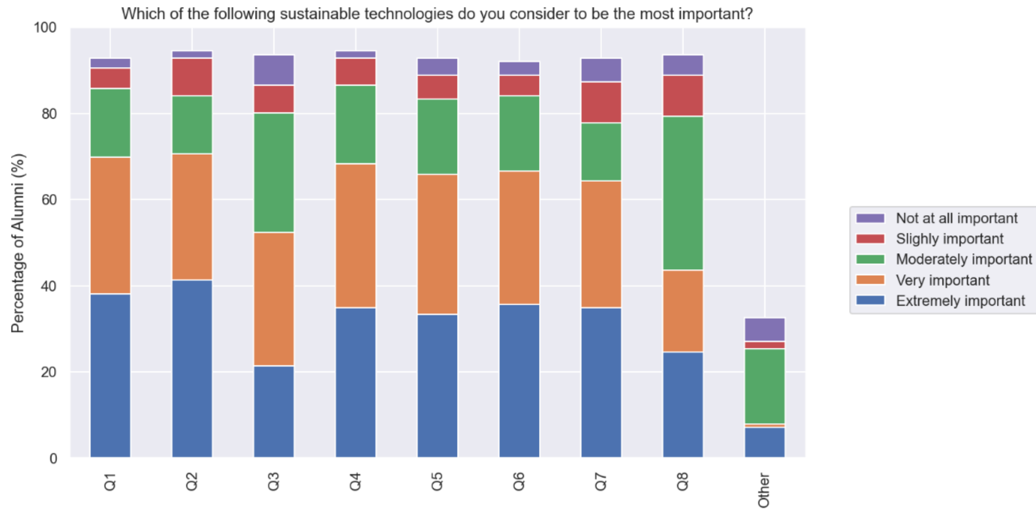


Figure 4.17. Alumni response for question "Which of the following sustainable technologies do you consider to be the most important?"

Trend #2: Alumni Growth in Sustainability

A similar question was asked to understand the individual's involvement in engineering-sustainability related projects they have worked in the past as well as their organization involvement. The table (Table 4.1) below shows the percentage of projects alumni have worked on in the past, projects that their employer is currently involved with, and the difference in current organization involvement by their past projects. Individually, about 37% of students have worked with designs that comply with environmental standards and regulations. Currently, about 47% of their job function is currently involved with environmental standards and regulation. There has been a 10% increase in job functions that comply with environmental standards and regulation. As follows, it's shown that most of the alum (44%) work with design technologies that use less energy and reduce emissions. Based on past work, the difference is in designs that use less energy and emission has been a constant sustainable technology that companies use. Another sustainable technology that is growing in popularity is manufacturing processes that use less energy and natural resources. There has been an increase of 12% of alum that are currently using these sustainable technologies. About 22% of alum's organization is currently involved with manufacturing processes that use less energy and natural resources.

Table 4.1. Alumni Involvement in Sustainable Technologies

Sustainable Technologies/Measure	Worked in the past (%)	Organization current involvement (%)	Difference (Δ%)
Designs that use less energy or reduce emissions	40	44	+4
Designs that comply with Environmental Standards and Regulations	37	47	+10
Designs that use renewable/recyclable/recycled materials	21	30	+9
Designs that reduce material waste in manufacturing	27	35	+8
Manufacturing processes that use less energy and natural resources	22	30	+8
Manufacturing processes that produce less pollution and greenhouse gases	10	22	+12
Products that can be disposed of safely, including biodegradable materials and packaging	15	19	+4
Products that require less packaging	8	13	+5
Other	10	13	+3

The ALMs used in the classroom must be applicable to current company's goals. Aligning with companies' goals can expand a student opportunity to use sustainability skills in a real-life application. It is best to understand the sustainability practices that influence the organization of where alumni work. Companies tend to be influenced by different internal and external motivators to use sustainability practices in their product life cycles. Figure 4.38 displays bar graphs that answer the question, “Which one is most likely to influence your organization's use of green design practices and procedures?” From left to right, each bar represents a respective statement:

Q1 Regulatory requirements
:
Q2 Rising energy costs
:
Q3 Ability to gain a market advantage
Q4 Long term return on investment
:
Q5 Personal sense of environmental responsibility
:
Q6 Government/industry incentives
:

Each bar graph represents a different question that is then used as a 5-point Likert scale of which participants rate to which they believe impacts sustainable influence in their company. Q2 and Q5 are shown to have the lowest influences in alumni’s organization. By far, the most influential component for companies is regulatory requirements (38.4%). Environment regulations attempt to protect public health and nature against industry and development which is essential in every type of organization. The next notable influence was ability to gain a market advantage (23.8%) and government/industry incentives (22.2%). Having a market advantage allows a company to be ahead of their competitors and provide well established goods and services to consumers. Having government/industry incentives allows engineers to use sustainability design concepts in their work field.

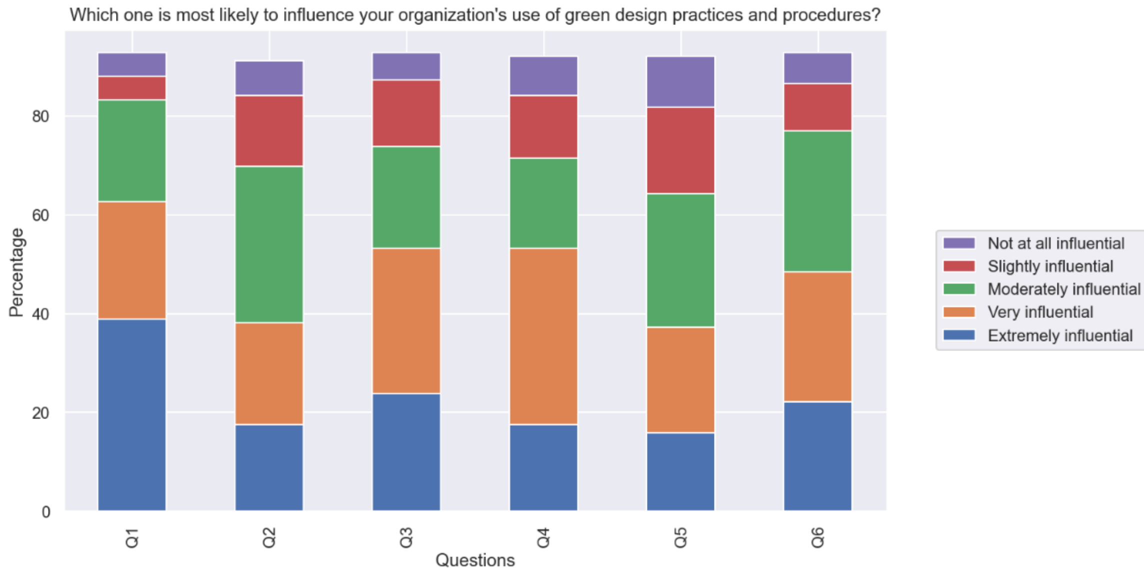


Figure 4.18. Alumni Response to "Which one is most likely to influence your organization's use of green design practices and procedures?"

Alumni Interview Input for RQ #2

Trend #1: Alumni-Sustainability Topics

As recalled, participant 2 had experience with sustainable development during his undergraduate career and has recognized that he was able to build a career around sustainability. He dived deep on his experience when learning about sustainability and realized that when he was at BSU, sustainability was not as popular as it is now.

> "What stood out to me the most is that I never knew that you could make a career out of it. I didn't think at the time there wasn't much publicity about environment, and climate change and policy, government policy. It wasn't as public, as it is now. And, as I got into the industry, it's grown so rapidly, and it's like every company, every manufacturing company is thinking about sustainability. They are thinking about decarbonization, and even the built environment. They're thinking about how they can reduce their carbon footprint and energy, trying to be as efficient as

possible in their practices. So, I think that that kind of surprised me or caught my attention after getting involved in the field"

This participant acknowledges the change in sustainability throughout the years. He noted the types of sustainability technologies companies have put into place which included the reduction of emissions and less energy usage. This aligns with the projects that alumni have participated in the past especially with designs that comply with environmental regulations and standards.

Another participant expressed his same thoughts on what sustainable technologies based on his experience. Participant 3 graduated from BSU with a Bachelor of Science in Mechanical Engineering. After completing his degree, he decided to pursue a master's degree in Business Administration. He recognized the importance of sustainability particularly in the business-related field. When asked about his thoughts about sustainability in engineering, he realized that BSU failed to teach him about sustainability technologies in any deep capacity, and everything learned was on his own and/or through his job. He believes his knowledge came from learning about sustainability by involving himself in the business field.

"I would say to focused on the standards and regulations. Also, teaching the students the meaning of sustainability related to business. For example, what are all of the environmental compliance regulations like WEEE which it's a German regulation. Because I don't recall hearing anything about regulations and standards… even the basics standards were never mentioned. As an engineer, it's good to know how your designs could be impacted."

This participant was able to work in the manufacturing and business side in his organizations and has been able to recognize the lack of use in sustainability for engineers. By adding more examples that use environmental standards and regulations can impact future engineers.

CHAPTER FIVE: DISCUSSION AND CONCLUSIONS

Research Question #1 – How do we encourage engineering students' engagement in sustainability to improve learning?

<u>Results Findings</u>

Research Question #1 was created to understand students' response toward the ALMs. Bloom's taxonomy was used to expand on this idea because it was suggested that students are likely to be engaged when presented to ALMs (Yang & Koszalka, 2016). Based on the results, the implementation of ALMs to engineering courses has not been proven to add emphasis on sustainability for student engagement. This study used ALMs as a way to increase engagement, but it was difficult to know if ALMs were able to make a difference in engagement with sustainability due to low numbers of student interested in sustainability. Results may have varied due to the low number responses of the post surveys. Besides the low number of respondents, there were other inherent limitations with the study, including the difficulty in examining current student coursework and the inability to see student feedback on their courses regarding sustainability. Although ALMs were not necessarily proven to increase engagement directly, there were other ways that students and alumni found engagement within sustainability.

While sustainability is important to address in the classroom, increasing the opportunities for involvement is equally, if not more so, valuable for knowledge retention. Looking at the overall student data, many students were not as involved in sustainability projects despite their interest. Due to the lack of opportunities with sustainability within BSU, students were most likely responsible for finding and participating in sustainability projects on their own accord. As mentioned previously, participant 2 was able to heavily involve himself with sustainability by participating in different energy-related facilities, electives, and internships. Participant 2 was then able to create a career with sustainability after college and is still currently in the same position. BSU must promote sustainability related programs like reinstate BSU's Industrial Assessment Center (BS-IAC), promote study abroad programs like the Green Program and be more involved with The Environmental Health, Safety and Sustainability Department at BSU to increase sustainability involvement at BSU.

Another common trend found in the student and alumni data was the interests in sustainability. In Spring 2021, more women were extremely interested in sustainability technologies as shown in Figure 4.10. While not specified, it's possible that the interests in green and sustainability information grew through the ALMs that were presented that semester. In Spring 2021, a female alumni presented about her past work in commercial-grade refrigeration. Although having a presentation by an alumni raised engagement in all students, the females were more engaged compared to males as seen in Figure 4.10. This could be partially due to the presenter also being female. During the lecture, there were more active participants with follow-up questions. In the following semester, it can be assumed that these presentations helped increase student engagement through the horizontal method. The Environmental Health, Safety and Sustainability Department helped put together a scavenger hunt for students to see real-life examples of sustainability used by BSU. These types of ALMs allow students to feel more involved in sustainability technologies as seen in pre- and post- surveys (Figure 4.8 and Figure 4.9).

Looking closer into gender, a trend found in the alumni data showed the difference in confidence levels as seen in Figure 4.28. In Figure 4.27, most participants were able to articulate their interest in sustainability, although Figure 4.28 shows that 50% of women were not confident in applying sustainability into their design work. This contradiction shows that when being introduced to sustainability, women are interested in learning about it but are reluctant to apply these concepts to their design work. Using this data, it is clear that BSU must empower women in sustainability technologies to help increase their confidence. To accomplish this, there should be discussion about how to incorporate sustainability concepts in a structured way that helps women feel more included. Adding modules with female guest speakers was shown to female students' interest in sustainability, though more data must be collected to see if this would increase their confidence levels.

Age was another factor that presented some limitations, as most student participants were ages 18-25. In the alumni data, there was more disparity in the results which allowed us to see the difference in interests and confidence level with age. The younger generations were shown to less interested/neutral in sustainability. Based on other research findings, it was expected that the younger generation would be more interested in sustainability than the older generation (Wiernik et al., 2013). In fact, the older generation showed more interests in sustainability. It's possible, this trend is seen dependent on the experience they have with sustainability. Despite the difference in age, most participants were not confident in applying sustainability into their design. A few who were older were confident in applying sustainability into their designs, but it's assumed that they were now comfortable with the idea after many years of industry.

Those who lack age and experiences are less likely to know how to add sustainability into their designs. This presents BSU another opportunity to examine how to bridge the gap in confidence between undergraduates and career professionals in sustainability.

Diversity at BSU is still very much a work in progress; in student data, there were not any Black/African American participants. For the Latino/Hispanic demographic, data showed that they followed the same trends as the White subgroup regarding involvement with sustainable technologies, where most were categorized as neutral. This trend was unexpected due to past research suggesting that minority groups tend to lack concern in environmentalism (Johnson et al., 2016). When looking at personal interests, Latinos/Hispanics were the most interested in sustainability technologies. With involvement in alumni, ethnic groups like Latinos/Hispanics and Black/African American were more interested in sustainability than any other group. While these groups were not extremely confident in applying sustainability, these two subgroups were extremely interested in sustainability technologies. This data suggests that much of the involvement comes from different ethnic groups.

Instructors Module Reflection for RQ #1

The student survey was created to observe the before and after trends. Although there were other trends founded in the classroom when teaching about sustainability. During the lectures, engagement was shown in various ways. Despite not being included in the results due to low respondents in the post survey, engagement from Spring 2022 increased when the presenter talked about their personal experience with their participation in a sustainable study abroad program. The presenter was able to create an in-class discussion with the students about the study abroad program and hydropower.

This study abroad program is an experiential education program that looks at issues regarding sustainable development. This particular program allowed the presenter to go to Nepal and install a solar grinding mill to a rural village. Despite this program being advertised in the study abroad office, many students were unfamiliar with it. By observation, females were very interested in the presentation. Many females' students were not outspoken during the lectures but after the lecture, many females' students wanted more information about the program. A few males in this cohort were also interested in obtaining more information about the Green Program. The inability to be outspoken and speak during the lecture may be related to female's lack of confidence and their sense of belonging (Clark et al., n.d.). Females' students failed to obtain confidence to ask questions during a lecture despite having a female professor. In terms of involvement, females' students were more eager to learn more about the study abroad experience than men. Females' connection to ecofeminist may allow the students to seek opportunities that are nature structure. Allowing students to hear about projects that they are able to participate in while learning about sustainability increased engagement overall during the lecture. Engagement increased after hearing about real-life problems and providing resources to allow the student for a possible chance of participation.

Based on observations, students would struggle to stay engaged when they were unknowledgeable about a sustainable topic. Each semester, every student was required to watch a video related to the disadvantages of hydropower in terms of sustainability. In the end of the video, they were required to identify the tradeoffs of TBL that arise from obtaining energy from hydropower. The video identified ways that hydropower negatively impacts wildlife. The students then had to identify the pros in environmental pillar from the triple bottom line, and students would struggle because it was their first time learning about hydropower. Without a background knowledge of hydropower, students struggled to identify basic positive aspects of hydropower. If a student were to apply this concept in another course related to hydropower, it's possible their engagement will increase. By adding more modules throughout the semester or by each grade level can improve students' retention on sustainability. Students respond well to ALMs in tandem with other teaching methods, which can increase their engagement with hydropower in this case to the horizontal method. Much of the efficacy comes down to repetition and consistent exposure to sustainability concepts, which ALMs aim to present.

Research Question #2 – Are the sustainability topics used in ALMs relevant to industry applications for mechanical engineering?

Introductory courses are great at providing a foundation for sustainability, but freshman and sophomore-level students can sometimes lack basic engineering skills specifically related to industry applications. Without an understanding of industry applications, students will struggle to understand the use of sustainability technologies within their industries. To address this, the ALMs must specifically be related back to real-life examples; for example, students and alumni can collaborate to further their understanding of sustainability and what types of projects are being worked on in the workforce today. Creating a connection with alumni and the students is important because BSU students are likely to work in similar job functions as alumni due to the networking opportunities that BSU offers. Introducing alumni's work-related examples at BSU can improve a student's chance of obtaining a job after college as well as increase their understanding of sustainability and their confidence levels in applying sustainability.

Research question #2 looked at the relevant sustainability topics being introduced in engineering courses and the ones that alumni have used in the past. Adding modules to students relevant to alumni can increase engagement as well. While this research question focused mainly on the projects that alumni have done in the past, it's important to see the perspectives of students related to sustainability. By first evaluating the student data in Spring 2021, it was clear that the majority of the group agreed that manufacturing processes that use less energy and natural resources are the most important sustainable technologies, while the least important was creating products that use less packaging (Figure 4.34). This group of students were presented with a guest speaker who spoke about the different strategies they used to reduce the energy usage in commercial-grade refrigeration. The guest speaker also spoke of the different environmental standards and regulations they used in her projects, which shaped some students' values and beliefs on what is important regarding sustainability. As they typically have limited exposure to sustainability, these students are also likely to shape their perspectives based on whichever ALMs they are exposed to.

In Fall 2021, the students gave similar results to those in Spring 2021, but after being presented with ALMs, there was a noticeable split in responses regarding what students felt was important in sustainable technologies; in this case, the split dealt with designs that use renewable/recycled materials and manufacturing processes that produce less pollution and greenhouse gasses (Figure 4.36). Fall 2021 data focused mostly on the hydropower presentation where these students learned about the new designs that allows hydropower to emit less greenhouse gasses. Apart from the in-class discussion, the scavenger hunt was another ALM implemented by BSU in which many of the designated spots focused on recycling and the processes to use less pollution and greenhouse gasses like the use of geothermal power, reduction of food waste at the Boise River Café, and textbook/battery recycling at the Bronco Shop at the Micron Business and Economics Building (MBEB). Of course, there is a case to be made about how these ALMs affected student perceptions of sustainability and its applications.

When alumni were asked the same question, the majority were able to agree that designs that comply with environmental standards and regulations with the least of importance was designs that use renewable/recyclable/recycled energy (Figure 4.37). The next category with importance is designs that use less energy or reduce emissions. The students' responses were close to alumni results, but they were not consistent per semester. To help align these responses with one another, ALMs should be redefined to add modules that will add sustainability topics that are applicable in industry. By redefining the ALMs, if students were to do this survey again, the results should show similar trends. Based on results and alumni interviews, many agreed that environmental standards and regulation is typical in all organizations. Projects that involve learning about environmental standards and regulations should be added in upper-level courses to introduce students to sustainability related real-life problems. Gradually adding more real-life examples that are relevant to alumni projects and their major can increase student engagement.

A separate question was asked to alumni to understand alumni's different job functions they have worked on in the past and are currently involved with related to the sustainable technologies that were listed. The most common measures companies have taken was paying more attention to designs that comply with environmental regulations; data showed an increase of 10% more people working on these designs. Most alumni are in organizations that create designs that comply with environmental regulations, which partially explains why so many alumni felt this aspect was important. Alumni also typically work with designs that use less energy or reduce emission, but despite alumni working on these designs previously, there has only been a 4% increase in people working with these designs, meaning that this is much more valuable for students to learn as there is limited focus on these designs. Another sustainable technology that is growing in importance is manufacturing designs that produce less pollution and greenhouse gasses, which showed a 12% increase in those who work on those types of designs.

Rather than looking at the opinions about sustainable technologies in alumni, a question was asked to see how they expect their organization to be influenced to use green practices and procedures (Figure 4.38). About 37% agreed that the biggest influence was regulatory requirements. This was expected knowing that the majority of alumni have worked with this in the past and were able to establish the importance of this sustainable measure. Rising energy costs and personal sense of environmental responsibility were the least influential to these organizations. The alumni survey was collected during the summer which makes one wonder if the results change by season, especially those dependent on job location. With inflation on the rise, there’s a possibility that an organization would be more receptive to changes based on energy costs this year.

Students have seen different examples that are somewhat related to what alumni participants have seen in the past. Based on the data, there must be more emphasis on environmental standards and regulation. This addition can be added in upper-level division courses especially in courses like senior design. Regulations play a huge role in all engineering projects in real-life, yet almost all the interviewers didn’t recall learning about different standards and regulations.

Conclusion

The questions explored in this study were:

1. How do we encourage students’ engagement in sustainability to improve learning?
2. Are the sustainability topics used in ALMs relevant to industry applications for mechanical engineering?

To review these questions carefully, multiple surveys to students and alumni were distributed alongside with alumni interviews. The purpose of the alumni survey and interview was to understand the outside perspective of those who have done their undergraduate at BSU as well as their experiences in their organization. Allowing alumni to be part of the study was useful in demonstrating the gap between real-life industry sustainability applications and the undergraduate education at BSU. The student survey allowed us to gather data regarding the ALMs that were being presented as well as understand student perceptions on sustainability.

Student demographics were able to delineate several factors that related to gender, age, and ethnicity. Gender and age in particular showed a trend of high interest but low involvement in sustainable technologies and concepts. Based on the student and alumni data, female engineers and practicing engineers have a higher personal interest level in sustainability than males. This trend is important for the continuation for sustainability modules in the curriculum. Understanding engagement related to gender and age can improve the curriculum. By increasing students' engagement, it's likely they will be more involvement in extracurricular activities related to sustainability.

For students, there was not a wide range of ages; this section was included primarily to see the difference in alumni data. The alumni data showed the difference in interests related to sustainability. The older generation (60+ of age) is far more involved in sustainability than the younger generation. This trend came as a surprised since studies in the past has shown that the younger generation tend to be more interested about learning about sustainability (Johnson et al., 2016; Wiernik et al., 2013). The older generation is also more confident in applying sustainability due to their year of experiences. Based on the student data, there was not a diversity in age but despite of age, students are eager to be involved in sustainability design work. Taking this as an advantage can reshape the ALMs to increase engagement in the classroom.

When examining ethnicity, it was clear that ethnic groups were slightly more involved and interested in sustainability than the majority group (White). Which came as a surprised since research has shown that minority groups tend to concern less about sustainability issues due to lack of resources and time (Medina et al., 2019). Understanding minority groups growth in interests with sustainability information (Seen in Figure 4.22, 28 and 29), will allow for opportunities for involvement in sustainability work. BSU lacks in diversity but there has been a growth in Hispanic and Latino students in the engineering field (*STEM Enrollment Demographics - Institute for Inclusive and Transformative Scholarship*, n.d.). With more minority groups coming to BSU, this trend is viable to assist the upcoming students.

The alumni demographics were included to get a better diversity group in gender, age, and ethnicity. The alumni data was valuable due to their understanding of the BSU curriculum and their perspectives in industry. While age and gender had the same trends, females' confidence levels were extremely low compared to the males. This trend shows that there must be a readjustment to help future female engineers with confidence in applying sustainability concepts. It can be argued that females are often left behind when it comes to upcoming technologies and practices, which explains the low confidence levels shown by the data. It should be noted that the confidence levels were evaluated by post-graduation and not their current confidence level. It is clear that ALMs should aim to address this and find ways to ensure female engineering students are more included and encouraged in projects, coursework, etc.

This study focused on engagement by analyzing the involvement, interests, and confidence levels that students and alumni experience. Involvement was difficult to evaluate with students due to the low sustainability opportunities BSU offers. Although by instructor's narrative, when students were presented with possible sustainability related projects that they are able to participant, students were eager to get involved in a similar project. Alumni who were able to participate in sustainability extracurricular activities as Participant 2 have even create a career around sustainability. Students are eager to be involved but lack the opportunity the university provides. Creating a relationship with The Environmental Health, Safety, and Sustainability Department, reinstating BSU's Industrial Assessment Center (BS-IAC) and adding more in-class presentations with alumni can allow students to be more involved in sustainability. By being involved in projects, there can be an increase in confidence levels.

Being involved in sustainability is viable for student retention but their involvement should be related back to industry practices. Based on the results of the alumni data and interviews, a widespread of participants were able to recognize that projects that relate back to environmental standards and designs that reduce emissions are considered to be the most important sustainable technologies. Currently the ALMs being presented cover different sustainable projects that are not consistent with alumni practices. By combing the results found from research question #2 and the ALMs, students will be in a better position when entering the work field.

These trends found in this study will be useful in developing new ALMs that will be used for upcoming students. The ALMs should be designed to increase involvement, engagement, and confidence levels within sustainability especially to within different genders, ages, and ethnicity. The ALMs should also be applicable to engineers and use sustainable technologies as discussed in Chapter 4. Adding projects that relate to real-life examples can increase engagement overall in students. These ALMs should be applied in all courses, especially those in upper divisions. This will reinforce their understanding of sustainability through repetition and increase their engagement by providing interesting real-life application examples. By recognizing the trends from this study, BSU will be able successfully integrate sustainability into the curriculum.

Future Work/Recommendations

When introducing sustainability to the curriculum, there was an addition of only one lecture that covers sustainability. Limiting the course time to one lecture creates a barrier to teach students about other sustainability practices. During the lectures, students would learn about the triple bottom line and the sustainability pillars. As we know, foregoing ALMs that deal with sustainability can cause a lack of engagement with content, and this study aimed to highlight sustainability topics that are currently being used in industry which should be taken into consideration when creating new ALMs for upcoming years.

During these lectures, students would apply the triple bottom line to their in-class projects without the guidance of the presenter. It is recommended for the future researcher to create a finer connection between the presenter and the course instructor. That connection will allow better feedback on the ALMs and increase participant responses, especially for the post-survey results.

If future researcher would like to expand this project to different departments around BSU to understand the engagement dependent on major, the survey’s displayed in the appendix (Appendix A and B) would be a great way to start. This research study focused on the freshman and sophomore-level standing who were majoring in mechanical engineering and engineering plus. Similar results were found for both majors and raises questions about if the similar results are caused by their education level. If future researcher would like to expand their research on education level, it would be best to create a section focusing on upper-division students and those who have had exposure related to sustainability to obtain meaningful data.

Using extra credit as an incentive to participate in surveys was found to be unreliable, as early student courses are easier and thus students do not feel any urgency to have extra points. This means that focusing on upper-division students works twofold: Upper-level courses are more difficult, so more participants will be more motivated to respond to the survey in addition to upper-division students having more exposure to sustainability.

When utilized correctly, it is a safe assumption that integrating ALMs into lower and upper-division courses increases student engagement with sustainability, and after gathering data from a variety of sources, including undergraduate students and alumni of diverse demographics (age, gender, ethnicity), one thing is certain: The horizontal method is beneficial to all parties involved, and with the data collected by this study, there are plentiful opportunities to integrate the horizontal method in ways that address the current weaker areas of the curriculum at BSU regarding sustainability.

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APPENDIX A

Industry Survey

Sustainability in Industry

The purpose of this survey is to collect information on knowledge, attitudes and behaviors on Boise State's Alumni related to sustainability. This study attempts to collect information about how incorporating sustainability courses affects students understanding of these concepts and how students utilize them as practicing engineers. Your feedback will be used to help us improve current engineering courses.

If you choose to complete the survey it will take you about 10-15 minutes. More information about the survey and the research is included below.

Eligibility
The survey is intended for individuals who are (a) 18-years old or older and (b) graduated from Boise State University with an engineering degree

Risks and Discomforts
This study involves no foreseeable serious risks. We ask that you try to answer all questions; however, if there are any items that make you uncomfortable or that you would prefer to skip, please leave the answer blank.

Protection of Privacy and Confidentiality
Your data will be collected anonymously. All data collected will be securely stored, and the researchers will make every effort to protect your confidentiality. However, if you are uncomfortable answering any of these questions, you should skip them.

Voluntary Participation
You do not have to be in this study. Participation is voluntary. You may choose not to take part and you may choose to stop taking part at any time without penalty.

Contact Information
If you have any questions or concerns about this study or if any problems arise, please contact the researchers at the following points:

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If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM (Mountain time), Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

If you would like a copy of this form for your reference, you may print this out.

Consent
By beginning the survey you certify that you are at least 18 years old, have read the consent form presented on the previous screen, that you understand that information, and that you agree to voluntarily participate in this research.

Choosing the 'Yes' option below indicates your consent to participate in this survey. When you click the right arrow at the bottom of this page after clicking 'Yes' you will be taken to the first question in the survey.

Choosing the 'No' option below indicates that you decline participation in this survey. When you click the right arrow at the bottom of this page after clicking 'No' you will be taken to the exit point of the survey.

○ Yes

- No

What gender do you identify as?

- Female
- Male
- Prefer not to say

Please specify your ethnicity

- White
- Black or African American
- Latino or Hispanic
- Asian
- American Indian or Alaska Native
- Native Hawaiian or Pacific Islander
- Other/Unknown
- Prefer not to say

Which category best describes your age?

- 21-25
- 26-30
- 31-35
- 36-45
- 46-50
- 51-55
- 56-59
- Over 60 years of age

Where do you live?

- Northeast U.S.
- Southeast U.S.
- Midwest U.S.
- Southwest U.S.
- Northwest U.S.
- West Coast U.S.
- Outside of the U.S.

I have been employed as an Engineer

- Less than 3 years
- 3 - 6 years
- 7-10 years
- 11-20 years
- More than 20 years
- ______ Not employed as an engineer (other type of professional)
- Not employed as an engineer (student)

Which of the following best describes your principle job function?

- Design/Development Engineering
- Consulting/Professional Services
- Research & Development Engineering
- Production Engineering
- General or Corporate Management
- Testing, reliability assurance, quality control
- Engineering Management
- Marketing/Sales
- Education

- ○ Retired
- ○ Student
- ○ ______ Other

How involved are you with sustainability or sustainable technologies in your organization?

- ○ Extremely involved
- ○ Somewhat involved
- ○ Neither involved nor uninvolved
- ○ Somewhat involved
- ○ Not at all involved

Which of the following sustainable technologies have you worked in the past year?

- ☐ Designs that use less energy or reduce emissions
- ☐ Designs that comply with Environmental Standards and Regulations
- ☐ Designs that use renewable/recyclable/recycled materials
- ☐ Designs that reduce material waste in manufacturing
- ☐ Manufacturing processes that use less energy and natural resources
- ☐ Manufacturing processes that produce less pollution and greenhouse gases
- ☐ Products that can be disposed of safely, including biodegradable materials and packaging
- ☐ Products that require less packaging
- ☐ ______ Other

Please check with which of the following sustainable technologies are your organization currently involved in

- ☐ Designs that use less energy or reduce emissions
- ☐ Designs that comply with Environmental Standards and Regulations
- ☐ Designs that use renewable/recyclable/recycled materials
- ☐ Designs that reduce material waste in manufacturing

- ☐ Manufacturing processes that use less energy and natural resources
- ☐ Manufacturing processes that produce less pollution and greenhouse gases
- ☐ Products that can be disposed of safely, including biodegradable materials and packaging
- ☐ Products that require less packaging
- ☐ ________ Other

Which of the following sustainable technologies do you consider to be the most important?

	Extremely important	Very important	Moderately important	Slightly important	Not at all important
Designs that use less energy or reduce emissions	○	○	○	○	○
Designs that comply with Environmental Standards and Regulations	○	○	○	○	○
Designs that use renewable/recyclable/recycled materials	○	○	○	○	○
Designs that reduce material waste in manufacturing	○	○	○	○	○
Manufacturing processes that use less energy and natural resources	○	○	○	○	○
Manufacturing processes that produce less pollution and greenhouse gases	○	○	○	○	○
Products that can be disposed of safely, including biodegradable materials and packaging	○	○	○	○	○
Products that require less packaging	○	○	○	○	○
Other	○	○	○	○	○

How do you expect that your organization's involvement in incorporating sustainable and/or green design specification into its work will change in the coming year

- Increase a great deal
- Increase somewhat
- No change
- Decrease somewhat
- Decrease a great deal

Which one is most likely to influence your organization's use of green design practices and procedures?

	Extremely influential	Very influential	Moderately influential	Slightly influential	Not at all influential
Regulatory requirements	O	O	O	O	O
Rising energy costs	O	O	O	O	O
Ability to gain a market advantage	O	O	O	O	O
Long term return on investment	O	O	O	O	O
Personal sense of environmental responsibility	O	O	O	O	O
Government/industry incentives	O	O	O	O	O

Outside of work, how interested are you personally in green and sustainability information and causes?

- Not at all interested
- Somewhat not interested
- Neutral
- Somewhat Interested
- Extremely Interested

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Projects for my job have limited sustainability considerations.	O	O	O	O	O
I am expected to apply sustainable engineering practice in my work.	O	O	O	O	O
I could have applied sustainable engineering practice more in my work.	O	O	O	O	O
Practicing engineers should apply sustainable engineering practice to more elements of their projects.	O	O	O	O	O
Fully incorporating sustainable engineering practice into a real-world project requires too much time to be practical.	O	O	O	O	O
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	O	O	O	O	O

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Sustainability is just a word used in industry for promotion and public image.	O	O	O	O	O
Sustainability is currently a shared vision among engineers working in my company.	O	O	O	O	O
I will not work for companies that do not value sustainable engineering practice.	O	O	O	O	O
I enjoy solving problems that incorporate complex social, environmental, and economic elements.	O	O	O	O	O
I want to apply sustainable engineering practice to every project I work on	O	O	O	O	O

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Learning about sustainable engineering practice is necessary to be a responsible engineer.	O	O	O	O	O
The application of sustainable engineering practice creates better engineering solutions	O	O	O	O	O

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Engineering professional skills are more important to learn about than sustainable engineering practice.	O	O	O	O	O
Technical engineering topics are more important to learn about than sustainable engineering practice.	O	O	O	O	O

Before working in industry, how confident were you in ability to apply sustainability into your designs?

- O Extremely confident
- O Very confident
- O Moderately confident
- O Slightly confident
- O Not confident

Where did you learn about applying sustainability into your designs?

- ☐ Undergraduate studies
- ☐ In the workplace
- ☐ Professional workshops
- ☐ On the job training
- ☐ On my own
- ☐ [ ] Other

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APPENDIX B

Student Survey

Sustainability in Education

The purpose of this survey is to collect information on knowledge, attitudes and behaviors on Boise State's engineering students related to sustainability. This study attempts to collect information about how incorporating sustainability courses affects students understanding of these concepts and how students utilize them as practicing engineers. Your feedback will be used to help us improve current engineering courses.

If you choose to complete the survey it will take you about 10 minutes. More information about the survey and the research is included below.

Eligibility
The survey is intended for individuals who are (a) 18-years old or older and (b) are currently enrolled in a STEM undergraduate degree program which include, Mechanical Engineering, Electrical Engineering, Civil Engineering and Engineering Plus.

Risks and Discomforts
This study involves no foreseeable serious risks. We ask that you try to answer all questions; however, if there are any items that make you uncomfortable or that you would prefer to skip, please leave the answer blank.

Protection of Privacy and Confidentiality
your data will be collected anonymously. All data collected will be securely stored, and the researchers will make every effort to protect your confidentiality. However, if you are uncomfortable answering any of these questions, you should skip them.

Voluntary Participation
You do not have to be in this study. Participation is voluntary. You may choose not to take part and you may choose to stop taking part at any time without penalty.

Contact Information
If you have any questions or concerns about this study or if any problems arise,

please contact the researchers at the following points:

Noah Salzman, Ph.D.
Assistant Professor of Electrical and Computer Engineering
Boise State University, College of Engineering
E-mail: noahsalzman@boisestate.edu

or

Karen Perez
Graduate Research Assistant
Boise State University, College of Engineering
E-mail: karenperez11@boisestate.edu

If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM (Mountain time), Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

If you would like a copy of this form for your reference, you may print this out.
Qualtrics Survey Software

Consent
By beginning the survey you certify that you are at least 18 years old, have read the consent form presented on the previous screen, that you understand that information, and that you agree to voluntarily participate in this research.

Choosing the 'Yes' option below indicates your consent to participate in this survey. When you click the right arrow at the bottom of this page after clicking 'Yes' you will be taken to the first question in the survey.

Choosing the 'No' option below indicates that you decline participation in this survey. When you click the right arrow at the bottom of this page after clicking 'No' you will be taken to the exit point of the survey.

- Yes
- No

What gender do you identify as?

- Female
- Male
- Prefer not to say

Please specify year of education level.

- Freshman
- Sophomore
- Junior
- Senior
- Other

Please specify your major

- Mechanical Engineering
- Electrical Engineering
- Civil Engineering
- Engineering Plus
- Other

Please specify your ethnicity.

- White
- Black or African American
- Latino or Hispanic
- Asian
- Native American or Alaska Native
- Native Hawaiian or Pacific Islander
- Other/Unknown
- Prefer not to say

Which category best describes your age?

- 18-20
- 21-25
- 26-30
- 31-35
- 36-40
- 41-45
- 46-50
- 51-55
- 56-60
- Over 60 years of age

How involved are you with sustainability or sustainable technologies in your engineering studies?

- Extremely involved
- Somewhat involved
- Neither involved nor uninvolved
- Somewhat involved

- Not at all involved

Which of the following sustainable technologies do you consider to be the most important?

	Extremely important	Very important	Moderately important	Slightly important	Not at all important
Designs that use less energy or reduce emissions	O	O	O	O	O
Designs that use renewable/recyclable/recycled materials	O	O	O	O	O
Designs that reduce material waste in manufacturing	O	O	O	O	O
Manufacturing processes that use less energy and natural resources	O	O	O	O	O
Manufacturing processes that produce less pollution and greenhouse gases	O	O	O	O	O
Products that can be disposed of safely, including biodegradable materials and packaging	O	O	O	O	O
Products that require less packaging	O	O	O	O	O
Other	O	O	O	O	O

Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?

- Not at all interested
- Somewhat not interested
- Neutral
- Somewhat Interested
- Extremely Interested

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?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Designing sustainable and/or green products results more product innovation	O	O	O	O	O
The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems	O	O	O	O	O
Projects that follow sustainable and/or green design principles typically have higher design costs	O	O	O	O	O
Incorporating sustainable and/or green design practices is too complex for my educational institution	O	O	O	O	O

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
It is too difficult to understand the complex elements of sustainability	O	O	O	O	O
I often discuss sustainable engineering topics with my classmates	O	O	O	O	O

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
My classmates are more interested in sustainable engineering practice than I am.	O	O	O	O	O
I need to learn about sustainable engineering now to be successful in my career.	O	O	O	O	O
Sustainability is just a word used in industry for promotion and public image.	O	O	O	O	O

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
It is important for me personally to apply sustainable engineering practice to every project I work on.	O	O	O	O	O
It is important for me personally to help others to learn to apply sustainable engineering practice in their projects.	O	O	O	O	O
I would prefer to learn about sustainable engineering more than any other engineering concept.	O	O	O	O	O

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Learning about sustainable engineering practice will take too much of my attention away from learning about technical engineering topics.	O	O	O	O	O
Other engineering disciplines have more sustainability considerations than in my field.	O	O	O	O	O
Course projects in my field have limited opportunities to apply sustainability.	O	O	O	O	O
I am expected to apply sustainable engineering practice in my design projects.	O	O	O	O	O
I could have applied sustainable engineering practice more in my design projects.	O	O	O	O	O
Sustainable engineering practice is applicable to every project in my my field.	O	O	O	O	O
I have many opportunities to apply sustainable engineering practice in my design projects.	O	O	O	O	O
Sustainable engineering practice is easily applied to real-world projects in my field.	O	O	O	O	O

Do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Valuing sustainable engineering practice will limit the industries I can work in.	O	O	O	O	O
Practicing engineers should apply sustainable engineering practices to more elements of their projects.	O	O	O	O	O
It is not practical to apply sustainable engineering practices to real-world engineering projects	O	O	O	O	O
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	O	O	O	O	O
Learning about sustainable engineering practices now will be useful for me in my career	O	O	O	O	O
Learning about sustainable engineering practices will help me to become a more responsible engineer	O	O	O	O	O
Applying sustainable engineering practice will help me to develop better engineering solutions.	O	O	O	O	O

List the courses where you have discussed sustainability.

APPENDIX C

Alumni Email

Hello ${m://FirstName},

With all the upheaval of the last year, I am excited to reconnect with our outstanding Mechanical Engineering alumni. Our programs are continuing to grow and hopefully, we will continue to maintain a high level of professional preparation for our graduates. Last year, we unveiled a new "modernized" ME curriculum that will be closely tied to the needs of our graduates and the communities they serve in the world.

In this same spirit, I would like to ask you to support a new initiative related to sustainability to better prepare our graduates for engineering positions now and in the future. We need your help to better understand the relevant issues in sustainability, how it is being used and how we can better educate students in these concepts. Essentially, if you were hiring an intern or graduate engineer, what would you like them to know!

To help support this work, I would like for you to devote about 10-15 minutes to answer the survey at the link provided below. We will keep your responses anonymous, but together they will help us define a better strategy for incorporating this important concept into our courses.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Lastly, I appreciate your willingness to give back to the program in this small way. I would also encourage you to get involved in other ways. Please reach out if your organization needs talented interns or graduates or if you are interested in senior design projects. We could also use your talents as a technical mentor or possibly an advisory board member. We would love to hear your story!

Regards,
Don Plumlee
Former ME Department Chair, Now Associate Dean for the College of Engineering
Boise State University

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

APPENDIX D

Student Email

Hello ${m://FirstName},

We invite you to participate in a research study exploring students' knowledge, attitudes, and behaviors related to sustainability in engineering. We would request that you click on the link below to take a brief survey. The survey will take approximately 10 minutes to complete. By linking to the survey website, you are acknowledging that you are 18 years of age or older.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Participation in this study is voluntary and has no effect on your grade in your engineering classes or any other classes. Your responses will be confidential, and no personally identifiable information will be shared beyond the project team.

Your participation is much appreciated.

Sincerely,

Noah Salzman | Assistant Professor | noahsalzman@boisestate.edu

Karen Perez | Graduate Research Assistant | karenperez11@boisestate.edu

Donald Plumlee | Associate Professor | dplumlee@boisestate.edu

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

APPENDIX E

IRB Approval

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: July 20, 2021

To: Noah Salzman cc: Don Plumlee

From: Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval for Modification - 126-SB20-077
Permeating Resiliency and Sustainability in Undergraduate Engineering

The Boise State University ORC has reviewed and approved the proposed modifications to your exempt protocol application.

Protocol Number: 126-SB20-077	Received: 7/19/2021	Review: Exempt
Expires: 4/15/2023	Approved: 7/20/2021	Category:

Your research is still exempt from further IRB review and supervision under 45 CFR 46.101(b). This exemption covers any research and data collected under your protocol as of the date of approval indicated above, unless terminated in writing by you, the Principal Investigator, or the Boise State University IRB. All amendments or changes (including personnel changes) to your approved protocol **must** be brought to the attention of the Office of Research Compliance for review and approval before they occur, as these modifications may change your exempt status. Complete and submit a Modification Form indicating any changes to your project.

This modification does not change your expiration date.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Office of Research Compliance

APPENDIX F

Sample of P-Value Code

```
def p_value(y,y2):
    '''
    description: calculates the p-value of 2 datasets
    ------------
    input: y - 1st dataset
           y2 - 2nd dataset
    ------------
    output: p - p-value
    '''

    import statistics
    from scipy.stats import chi2
    m = len(y)     #length of dataset
    G = np.concatenate((np.array(np.ones((m,1))), np.array([y]).T),axis=1)  #model matrix
    ML = np.linalg.inv(G.T@G)@G.T@y2

    #standard deviation
    sig = statistics.stdev(y)
    W = (1/sig)*np.eye(m) #weighting matrix

    #chi-square equation
    chi = (y2 - G@ML).T@(W**2)@(y2 - G@ML)

    #pvalue
    [m,n] = shape(G)
    p = 1- chi2.cdf(chi,m-n)
    return p

p_value(y,y2)
```

APPENDIX G

Sample of Machine Learning Code

```
def handle_non_numerical_data(df):

    df.infer_objects()
    df.fillna(0, inplace=True)

    columns = df.columns.values
    for column in columns:
        text_digit_vals = {}

        def convert_to_int(val):
            return text_digit_vals[val]

        if df[column].dtype != np.int64 and df[column].dtype != np.float64:
            column_contents = df[column].values.tolist()
            unique_elements = set(column_contents)
            x = 0
            for unique in unique_elements:
                if unique not in text_digit_vals:
                    text_digit_vals[unique] = x
                    x+=1

            df[column] = list(map(convert_to_int, df[column]))

    return df
```

APPENDIX H

Data Analysis Information

This appendix includes the p-value variables that was evaluated from the chi-square on from questions from the survey

Spring 2021: Post Test

Question 6: How involved are you with sustainability or sustainable technologies in your engineering studies?

Independent Variable	Group	P-Value
Gender	Male	0.06
	Female	0.05
	Prefer not to say	0.22
Ethnicity	White	0.05
	Latino or Hispanic	0.42
	Prefer Not to Say	0.42
	Other/Unknown	0.42
	Asian	0.22
Age	18-20	0.07
	21-25	0.29
	26-30	0.27
	31-35	0.02
	Over 60 years of age	0.42

Question 8: Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?

Independent Variable	Group	P-Value
Gender	Male	0.15
	Female	0.20
	Prefer not to say	0.28
Ethnicity	White	0.13
	Latino or Hispanic	0.31
	Prefer Not to Say	0.44
	Other/Unknown	0.44
	Asian	0.28
Age	18-20	0.16
	21-25	0.29
	26-30	0.31
	31-35	0.10
	Over 60 years of age	0.44

Fall 2021: Pre-Test Results

Question 6: How involved are you with sustainability or sustainable technologies in your engineering studies?

Independent Variable	Group	%
Gender	Male	0.11
	Female	0.24
	Prefer not to say	0.42
Ethnicity	White	0.13
	Latino or Hispanic	0.08
	Prefer Not to Say	0.34
	Other/Unknown	0.42
	Native Hawaiian	0.42
Age	18-20	0.12
	21-25	0.28
	26-30	0.44
	31-35	0.42
	36-40	0.42

Question 8: Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?

Independent Variable	Group	%
Gender	Male	0.27
	Female	0.14
	Prefer not to say	0.44
Ethnicity	White	0.23
	Latino or Hispanic	0.23
	Prefer Not to Say	0.14
	Other/Unknown	0.44
	Native Hawaiian	0.44
Age	18-20	0.18
	21-25	0.29
	26-30	0.44
	31-35	0.44
	36-40	0.44

Fall 2021: Post-Test Results

Question 6: How involved are you with sustainability or sustainable technologies in your engineering studies?

Independent Variable	**Group**	**%**
Gender	Male	0.21
	Female	0.22
	Prefer not to say	0.42
Ethnicity	White	0.20
	Latino or Hispanic	0.27
	Prefer Not to Say	0.42
	Other/Unknown	0.42
Age	18-20	0.25
	21-25	0.18
	31-35	0.22
	36-40	0.42

Question 8: Outside of your engineering studies, how are you interested are you personally in green and sustainability information and causes?

Independent Variable	**Group**	**%**
Gender	Male	0.29
	Female	0.18
	Prefer not to say	0.44
Ethnicity	White	0.27
	Latino or Hispanic	0.28
	Prefer Not to Say	0.44
	Other/Unknown	0.44
Age	18-20	0.18
	21-25	0.33
	31-35	0.44
	36-40	0.44

Alumni Results

Question 14: Outside of work, how interested are you personally in green and sustainability information and causes?

Independent Variable	Group	P-value
Gender	Male	0.15
	Female	0.07
Ethnicity	White	0.15
	Latino or Hispanic	0.16
	Prefer Not to Say	0.18
	Other/Unknown	0.10
	Black or African American	0.31
	Asian	0.44
Age	31-35	0.20
	36-45	0.09
	26-30	0.20
	21-25	0.20
	46-50	0.04
	Over 60	0.35
	56-59	0.28
	51-55	0.28

Question 18: Before working in industry, how confident were you in ability to apply sustainability into your designs?

Independent Variable	Group	P-value
Gender	Male	0.042
	Female	0.11
Ethnicity	White	0.024
	Latino or Hispanic	0.18
	Prefer Not to Say	0.001
	Other/Unknown	0.37
	Black or African American	0. 44
	Asian	0.28
Age	31-35	0.04
	36-45	0.05
	26-30	0.10
	21-25	0.06
	46-50	0.12
	Over 60	0.10
	56-59	0.28
	51-55	0.28

Survey Student Results-Spring 2021

Survey Question	$\overline{x}$	**s**	**Skewness**	**Kurtosis**
What gender do you identify as?	1.24	0.54	0.10	-0.18
Please specify year of education level.	1.51	1.67	0.34	-1.71
Please specify your major	0.89	1.28	1.12	-0.01
Please specify your ethnicity.	2.43	0.98	-1.35	1.09
Which category best describes your age?	1.21	0.75	2.11	5.62
How involved are you with sustainability or sustainable technologies in your engineering studies?	0.86	1.00	0.97	-0.06
Which of the following sustainable technologies do you consider to be the most important?				
Designs that use less energy or reduce emissions	1.97	0.83	-0.25	-0.78
Designs that use renewable/recyclable/recycled materials	2.24	0.83	-0.80	-0.13
Designs that reduce material waste in manufacturing	1.27	0.73	-0.47	-0.95
Manufacturing processes that use less energy and natural resources	2.00	0.78	-0.36	-0.27
Manufacturing processes that produce less pollution and greenhouse gases	2.32	0.88	-0.96	-0.29
Products that can be disposed of safely, including biodegradable materials and packaging	2.02	0.79	-0.39	-0.39
Products that require less packaging	1.75	0.95	0.11	-1.26
Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?	1.27	0.90	-0.33	-1.27
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?				

Designing sustainable and/or green products results more product innovation	1.37	0.75	-0.37	-0.51
The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems	1.08	0.92	0.05	-1.41
Projects that follow sustainable and/or green design principles typically have higher design costs	1.78	1.63	0.21	-1.49
Incorporating sustainable and/or green design practices is too complex for my educational institution	2.89	1.07	-0.91	0.23
Do you agree or disagree with the following statements?				
It is too difficult to understand the complex elements of sustainability	2.13	-1.37	-0.18	-1.42
I often discuss sustainable engineering topics with my classmates	2.13	2.09	0.40	-1.61
My classmates are more interested in sustainable engineering practice than I am.	0.78	1.27	1.11	-0.67
I need to learn about sustainable engineering now to be successful in my career.	1.35	0.82	-0.48	-0.98
Sustainability is just a word used in industry for promotion and public image.	1.89	1.34	0.27	-1.25
Do you agree or disagree with the following statements?				
It is important for me personally to apply sustainable engineering practice to every project I work on.	1.62	0.82	-0.41	-0.20
It is important for me personally to help others to learn to apply sustainable engineering practice in their projects.	1.48	0.98	-0.23	-0.97
I would prefer to learn about sustainable engineering more than any other engineering concept.	2.72	2.00	.0019	-1.79

Learning about sustainable engineering practice will take too much of my attention away from learning about technical engineering topics.	2.81	1.85	0.09	-1.84
Other engineering disciplines have more sustainability considerations than in my field.	2.70	2.13	-0.006	-1.86
Course projects in my field have limited opportunities to apply sustainability.	2.24	1.63	-0.174	-1.66
I am expected to apply sustainable engineering practice in my design projects.	2.00	1.68	0.07	-1.67
I could have applied sustainable engineering practice more in my design projects.	1.4	1.77	0.64	-1.45
Sustainable engineering practice is applicable to every project in my field.	1.89	1.71	0.106	-1.66
I have many opportunities to apply sustainable engineering practice in my design projects.	1.27	0.99	-0.04	-1.22
Sustainable engineering practice is easily applied to real-world projects in my field.	2.45	1.30	-0.144	-1.51
Do you agree or disagree with the following statements?				
Valuing sustainable engineering practice will limit the industries I can work in.	1.45	1.59	0.57	-1.32
Practicing engineers should apply sustainable engineering practices to more elements of their projects.	1.48	0.73	-1.077	-0.221
It is not practical to apply sustainable engineering practices to real-world engineering projects	2.11	1.26	0.13	-1.39
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	2.54	2.06	0.119	-1.79

Learning about sustainable engineering practices now will be useful for me in my career	1.32	1.35	0.57	-0.68
Learning about sustainable engineering practices will help me to become a more responsible engineer	1.35	0.71	-0.15	-0.30
Applying sustainable engineering practice will help me to develop better engineering solutions.	1.35	1.43	0.58	-0.86

Pre-Survey Student Results-Fall 2021

Survey Question	$\bar{x}$	s	Skewness	Kurtosis
What gender do you identify as?	1.65	0.83	0.65	-1.19
Please specify year of education level.	1.91	1.34	0.49	-0.08
Please specify your major	2.57	1.12	-0.07	-0.11
Please specify your ethnicity.	6.94	3.91	-0.56	-1.39
Which category best describes your age?	1.07	1.07	1.87	3.72
How involved are you with sustainability or sustainable technologies in your engineering studies?	1.50	1.42	0.42	-1.12
Which of the following sustainable technologies do you consider to be the most important?				
Designs that use less energy or reduce emissions	1.75	1.23	-0.14	-1.09
Designs that use renewable/recyclable/recycled materials	1.75	1.25	-0.04	-0.77
Designs that reduce material waste in manufacturing	1.71	1.19	-0.21	-1.06
Manufacturing processes that use less energy and natural resources	1.66	1.18	-0.13	-1.16
Manufacturing processes that produce less pollution and greenhouse gases	1.83	1.28	-0.16	-0.94

Products that can be disposed of safely, including biodegradable materials and packaging	1.87	1.33	-0.02	-0.06
Products that require less packaging	1.62	1.24	0.25	-0.54
Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?	2.19	1.73	0.43	-0.38
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?				
Designing sustainable and/or green products results more product innovation	2.98	1.92	-0.66	-1.21
The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems	2.24	1.82	0.45	-0.66
Projects that follow sustainable and/or green design principles typically have higher design costs	2.81	1.94	-0.39	-1.45
Incorporating sustainable and/or green design practices is too complex for my educational institution	2.00	1.89	0.60	-1.00
Do you agree or disagree with the following statements?				
It is too difficult to understand the complex elements of sustainability	1.92	1.84	0.72	-0.92
I often discuss sustainable engineering topics with my classmates	2.0	1.82	0.54	-1.05
My classmates are more interested in sustainable engineering practice than I am.	1.73	1.38	0.67	0.36
I need to learn about sustainable engineering now to be successful in my career.	2.68	2.00	0.002	-1.22
Sustainability is just a word used in industry for promotion and public image.	2.22	1.92	0.41	-1.25

Do you agree or disagree with the following statements?				
It is important for me personally to apply sustainable engineering practice to every project I work on.	2.93	2.21	-0.21	-1.37
It is important for me personally to help others to learn to apply sustainable engineering practice in their projects.	2.64	2.00	0.06	-1.81
I would prefer to learn about sustainable engineering more than any other engineering concept.	2.21	1.92	0.50	-1.00
Learning about sustainable engineering practice will take too much of my attention away from learning about technical engineering topics.	1.97	1.77	0.66	-0.69
Other engineering disciplines have more sustainability considerations than in my field.	2.13	1.7	0.50	-0.63
Course projects in my field have limited opportunities to apply sustainability.	1.84	1.62	0.73	-0.30
I am expected to apply sustainable engineering practice in my design projects.	2.08	1.70	0.49	-0.59
I could have applied sustainable engineering practice more in my design projects.	2.3	1.8	0.19	-0.96
Sustainable engineering practice is applicable to every project in my field.	2.33	1.88	0.36	-0.89
I have many opportunities to apply sustainable engineering practice in my design projects.	2.4	1.9	0.299	-1.00
Sustainable engineering practice is easily applied to real-world projects in my field.	2.4	1.89	0.28	-0.95
Do you agree or disagree with the following statements?				

Valuing sustainable engineering practice will limit the industries I can work in.	2.23	1.95	0.48	-1.11
Practicing engineers should apply sustainable engineering practices to more elements of their projects.	2.18	1.56	-0.32	-1.52
It is not practical to apply sustainable engineering practices to real-world engineering projects	1.79	1.78	0.97	-0.32
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	1.76	1.65	0.82	-0.17
Learning about sustainable engineering practices now will be useful for me in my career	3.18	2.27	-0.22	-1.37
Learning about sustainable engineering practices will help me to become a more responsible engineer	3.38	2.3	-0.31	-1.44
Applying sustainable engineering practice will help me to develop better engineering solutions.	3.13	2.23	-0.21	-1.34

Post-Survey Student Results-Fall 2021

Survey Question	$\bar{x}$	**s**	**Skewness**	**Kurtosis**
What gender do you identify as?	1.17	0.45	0.75	1.06
Please specify year of education level.	1.28	1.42	0.62	-0.87
Please specify your major	1.80	0.58	-2.78	6.34
Please specify your ethnicity.	0.60	0.81	1.58	2.61
Which category best describes your age?	1.11	0.47	2.19	8.15
How involved are you with sustainability or sustainable technologies in your engineering studies?	1.20	1.38	0.45	-1.74
Which of the following sustainable technologies do you consider to be the most important?				
Designs that use less energy or reduce emissions	1.48	0.78	-1.12	-0.34
Designs that use renewable/recyclable/recycled materials	1.08	0.74	-0.14	-1.11
Designs that reduce material waste in manufacturing	1.45	0.7	-0.38	-0.18
Manufacturing processes that use less energy and natural resources	1.31	0.83	-0.34	-0.89
Manufacturing processes that produce less pollution and greenhouse gases	0.91	0.70	0.11	-0.86
Products that can be disposed of safely, including biodegradable materials and packaging	1.34	0.72	-0.63	-0.79
Products that require less packaging	1.17	0.92	0.11	-1.01
Outside of your engineering studies, how interested are you personally in green and sustainability information and causes?	3.48	1.77	-1.03	-0.22
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?				

Designing sustainable and/or green products results more product innovation	1.08	0.74	0.31	0.03
The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems	0.85	0.77	0.66	0.27
Projects that follow sustainable and/or green design principles typically have higher design costs	2.11	1.15	0.24	-0.21
Incorporating sustainable and/or green design practices is too complex for my educational institution	1.94	1.3	0.11	-1.12
Do you agree or disagree with the following statements?				
It is too difficult to understand the complex elements of sustainability	2.05	1.55	0.14	-0.86
I often discuss sustainable engineering topics with my classmates	1.68	1.62	0.41	-0.96
My classmates are more interested in sustainable engineering practice than I am.	1.22	1.49	0.72	-0.65
I need to learn about sustainable engineering now to be successful in my career.	2.54	1.52	-0.48	-0.33
Sustainability is just a word used in industry for promotion and public image.	2.34	1.45	-0.33	-0.56
Do you agree or disagree with the following statements?				
It is important for me personally to apply sustainable engineering practice to every project I work on.	2.48	1.56	-0.73	-1.06
It is important for me personally to help others to learn to apply sustainable engineering practice in their projects.	2.22	1.83	0.06	-1.27
I would prefer to learn about sustainable engineering more than any other engineering concept.	1.6	1.57	0.522	-0.72

Learning about sustainable engineering practice will take too much of my attention away from learning about technical engineering topics.	2.08	1.72	0.3	-0.95
Other engineering disciplines have more sustainability considerations than in my field.	1.68	1.49	0.12	-1.21
Course projects in my field have limited opportunities to apply sustainability.	1.68	1.65	0.49	-0.83
I am expected to apply sustainable engineering practice in my design projects.	2.37	1.59	-0.23	-0.76
I could have applied sustainable engineering practice more in my design projects.	2.17	1.48	-0.48	-1.28
Sustainable engineering practice is applicable to every project in my field.	2.4	1.49	-0.74	-1.01
I have many opportunities to apply sustainable engineering practice in my design projects.	2.31	1.45	-0.71	-1.00
Sustainable engineering practice is easily applied to real-world projects in my field.	2.05	1.51	-0.31	-1.43
Do you agree or disagree with the following statements?				
Valuing sustainable engineering practice will limit the industries I can work in.	2.14	1.75	0.11	-1.28
Practicing engineers should apply sustainable engineering practices to more elements of their projects.	2.28	1.43	-0.46	-1.20
It is not practical to apply sustainable engineering practices to real-world engineering projects	1.57	1.31	0.21	-1.00
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	2.08	1.12	-0.71	-0.52

Learning about sustainable engineering practices now will be useful for me in my career	1.34	1.08	0.43	-1.05
Learning about sustainable engineering practices will help me to become a more responsible engineer	1.45	1.06	0.34	-1.14
Applying sustainable engineering practice will help me to develop better engineering solutions.	4.48	3.1	-0.27	-1.52

Survey Alumni Results

Survey Question	$\bar{x}$	**s**	**Skewness**	**Kurtosis**
What gender do you identify as?	1.11	0.43	0.65	1.77
Please specify your ethnicity	1.94	1.87	1.31	0.07
Which category best describes your age?	2.76	2.32	0.179	-1.43
Where do you live?	4.42	1.14	-2.06	3.45
I have been employed as an Engineer	3.39	2.02	-0.125	-1.44
Which of the following best describes your principal job function?	4.55	3.12	0.11	-1.03
How involved are you with sustainability or sustainable technologies in your organization?	1.76	1.07	-0.48	-1.00
Which of the following sustainable technologies do you consider to be the most important?				
Designs that use less energy or reduce emissions	3.38	1.52	-0.55	-0.48
Designs that comply with Environmental Standards and Regulations	3.57	1.45	-0.73	-0.15
Designs that use renewable/recyclable/recycled materials	2.88	1.43	-0.01	-0.61
Designs that reduce material waste in manufacturing	3.38	1.44	-0.46	-0.41

Manufacturing processes that use less energy and natural resources	3.25	1.5	-0.42	-0.59
Manufacturing processes that produce less pollution and greenhouse gases	3.28	1.55	-0.47	-0.62
Products that can be disposed of safely, including biodegradable materials and packaging	3.33	1.5	-0.56	-0.57
Products that require less packaging	2.94	1.48	-0.007	-0.86
How do you expect that your organization's involvement in incorporating sustainable and/or green design specification into its work will change in the coming year	2.88	1.28	-1.077	-0.077
Which one is most likely to influence your organization's use of green design practices and procedures?				
Regulatory requirements	2.96	1.8	-0.04	-1.59
Rising energy costs	2.38	1.65	0.37	-1.24
Ability to gain a market advantage	2.69	1.66	0.15	-1.33
Long term return on investment	2.51	1.55	0.31	-0.99
Personal sense of environmental responsibility	2.5	106	0.22	-1.24
Government/industry incentives	2.49	1.67	0.38	-1.25
Outside of work, how interested are you personally in green and sustainability information and causes?	2.86	1.27	-0.51	-0.42
Do you agree or disagree with the following statements?				
Projects for my job have limited sustainability considerations.	3.00	1.59	-0.31	-1.06
I am expected to apply sustainable engineering practice in my work.	3.36	1.68	-0.72	-0.85
I could have applied sustainable engineering practice more in my work.	3.26	1.58	-0.70	-0.67

Practicing engineers should apply sustainable engineering practice to more elements of their projects.	2.61	1.47	-0.44	-1.45
Fully incorporating sustainable engineering practice into a real-world project requires too much time to be practical.	3.14	1.46	-0.59	-0.46
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.	3.22	1.53	-0.54	-0.63
Do you agree or disagree with the following statements?				
Sustainability is just a word used in industry for promotion and public image.	2.99	1.61	-0.29	-1.044
Sustainability is currently a shared vision among engineers working in my company.	3.2	1.67	-0.63	-0.90
I will not work for companies that do not value sustainable engineering practice.	2.90	1.6	-0.37	-1.15
I enjoy solving problems that incorporate complex social, environmental, and economic elements.	3.11	1.89	-0.37	-1.57
I want to apply sustainable engineering practice to every project I work on	3.21	1.83	-0.54	-1.35
Do you agree or disagree with the following statements?				
Learning about sustainable engineering practice is necessary to be a responsible engineer.	2.86	1.96	-0.105	-1.74
The application of sustainable engineering practice creates better engineering solutions	2.99	1.92	-0.26	-1.65
Engineering professional skills are more important to learn about than sustainable engineering practice.	2.99	1.83	-0.32	-1.49
Technical engineering topics are more important to learn about than sustainable engineering practice.	2.98	1.85	-0.28	-1.53

Before working in industry, how confident were you in ability to apply sustainability into your designs?	3.00	1.85	-0.41	-1.44
Where did you learn about applying sustainability into your designs?	13.28	8.31	-0.49	-1.29