Implementing Sustainability and Resilience in An Undergraduate Construction Management Curriculum: Student's Knowledge and Attitude

Dazhi Yang
Educational Technology
Boise State Univeristy
Boise, USA
dazhiyang@boisestate.edu

Bhaskar Chittoori
Department of Civil Engineering
Boise State Univeristy
Boise, USA
bhaskarchittoori@boisestate.edu

Karen Krier
Educational Technology
Boise State Univeristy
Boise, USA
karenkrier@u.boisestate.edu

Kirsten Davis
Construction Management Department
Boise State Univeristy
Boise, USA
KirstenDavis@boisestate.edu

***Abstract*—This study investigates the outcome of implementing sustainability and resilience into an undergraduate construction management curriculum. Specifically, it examines the student's knowledge and attitudes toward sustainability and resilience before and after they were introduced to such concepts. Students' knowledge of sustainability was significantly improved in the post survey. However, neither students' attitude toward sustainability nor students' knowledge of resilience was significantly improved. The mixed results call for further investigations in both integrating sustainability and resilience and how to measure such concepts in educational settings - a highlighted challenge of such integration. This study provides insights into integrating sustainability and resilience in an undergraduate construction management curriculum to meet growing demands for sustainable construction practice.**

Keywords— sustainability, resilience, sustainable development, construction management, engineering education

I. Introduction

Learning about sustainability and resilience and their applications is integral to preparing future generations for unwanted disasters and to build a sustainable future for mankind [1]. The significance of sustainability for addressing social and environmental challenges across disciplines necessitates the inclusion of sustainability in formal curricula [2]. Considering that engineers play a critical role in problem solving, engineering curricula must integrate sustainability and resilience concepts. The need for engineers who can design solutions to maximize societal benefits while minimizing costs and environmental impacts is paramount.

Construction Management majors are trained to manage and oversee construction projects, from the initial planning and design stages to the final construction and completion. Construction Management majors need to learn sustainability and resilience concepts because these are critical factors in modern construction practices. Sustainable construction refers to building practices that are environmentally friendly and minimize the impact of construction on the natural environment. Resilient construction, on the other hand, refers to building practices that are designed to withstand and recover from natural disasters, climate change, and other disruptive events. Therefore, it is critical that professionals in construction management are equipped with the knowledge of sustainability and resilience for meeting the growing demands for sustainable construction practice and help build a more sustainable and resilient future.

However, limited research has been conducted with implementing both concepts in construction management curriculum simultaneously. This study investigates the outcome of implementing sustainability and resilience into an undergraduate construction management curriculum. Specifically it examines the student's knowledge and attitudes toward sustainability and resilience before and after they were introduced to such concepts. The guiding research question is: how does the integration of sustainability and resilience into the undergraduate construction management curriculum impact students' knowledge and attitudes towards such concepts?

II. Literature Review

Introducing sustainability and resilience concepts into the undergraduate curriculum will enhance students' understanding of such concepts [3]. Research shows that students who had been taught sustainability and resilience concepts during their studies are more like to expand their perspectives and incorporate sustainability and resilience design principles in their design decisions [4]. For example, first-year students who were introduced to the resilience concept and its design principles through a project-based learning approach were able to understand and apply resilience design principles in the real-world application [5]. Research also suggests that integrating sustainability and resilience concepts into undergraduate and graduate curriculum can not only improve students' understanding but also enhance their perceptions of the concepts [6].

To integrate sustainability and resilience into engineering education, some researchers argue that "stand-alone" courses are crucial, allowing students to learn such concepts through various contexts [3]. However, others consider that full programs may not be essential to introduce sustainability and resilience design principles in engineering design. Instead, incorporating the design principles into specific classes or including them within current classes that address the engineering design process can be a starting point [6]. A possible way to provide a valuable learning experience for students is to integrate resilience concepts into classes that involve a final design project. Furthermore, instructors can enhance their focus on sustainability and resilience by engaging students in practice and research activities [3]. To

We wish to thank the NSF for its support of this study (Award # 2013613).

further promote sustainability and resilience education, "capstone courses, undergraduate research programs, and design projects" can be incorporated [3]. However, due to a packed engineering curriculum, integrating sustainability and resilience concepts and their design principles into existing courses is the most applicable approach for such integration.

Studies on sustainable development with engineering students have revealed unsatisfactory levels of knowledge and understanding of sustainability and resilience. A survey examined the understanding of sustainability and resilience engineering in undergraduate and graduate students from various engineering disciplines has reported that students lacked knowledge of incorporating sustainability and resilience principles into engineering design [6]. Similarly, sustainability knowledge and skills are not deeply embedded within the engineering curricula [7]. The integration of sustainability in the students' senior design projects demonstrated that sustainability was incorporated due to instructors' expectations and requirements. In addition, students would be less likely to integrate sustainability concepts if not required. Even students are competent with the knowledge of sustainability and resilience, motivation would be an issue if such integration is not encouraged [8]. Therefore, instructors should collaborate with sustainability experts to make up their lack of knowledge of such concepts as well as to motivate students by providing students an opportunity to interact with industry experts [8].

III. Theoretical Framework

The definitions of sustainability and resilience in engineering and their respective design principles served as the foundation for the implementation of both concepts in the construction management curriculum. The definition of sustainability and resilience and their engineering design principles also provided the theoretical foundation for the research design and data collection instrument to measure students' knowledge and attitudes of both concepts in this study. For example, one of the questions asked students about the three aspects of sustainability (people, planet, and profit) in a knowledge-based multiple-choices question assessing students' knowledge of sustainability.

A. Sustainablity

Sustainability is generally defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." [9]. Design principles of sustainability, the three Ps (people, planet, and profit), are to achieve the balance between economic (profit), environmental (planet), and social (people) tradeoffs of an integrated system [10]. The design principles of sustainability guide us in decision-making while considering the economic, environmental, and social aspects of society. Sustainability design principles balance economic, ecological, and societal needs by being responsive to community impact, human health, and the environment, which meets the needs of the current generation while not compromising the ability for future generations to meet their needs.

Sustainability in construction management involves the use of environmentally responsible and resource-efficient practices that can benefit the environment, economy, and society. By incorporating sustainable practices into construction projects, professionals in construction management can help create a more sustainable future.

B. Resilience

Resilience is defined as the ability to recover quickly from an adverse event [11]. The four design principles of resilience are Robustness (strength and ability to withstand adverse events to reduce failure), Redundancy (substitutable elements of a system), Resourcefulness (the ability to identify and apply resources), and Rapidity (timely recovery). Resilient design is intended to prevent failure, reduce the adverse consequences impacting people, environment, and economy, and shorten the time for recovery when facing an adverse event [12]. The practice of resilience involves not only technical and engineering expertise but also the consideration of the social, environmental, and economic impact of the technical solution.

Resilience in construction management involves the use of strategies and practices that promote the ability of buildings and infrastructure to withstand and recover from natural disasters, climate change, and other disruptive events. By incorporating resilient practices into construction projects, professionals in construction management can help create more resilient communities and a more secure future.

IV. Context of Study

This study is part of a larger externally funded project that aims to improve students' ability to create sustainable and resilient engineering designs and provide sustainable solutions to societal needs and development. The project aims to transform undergraduate engineering education by instilling sustainability and resiliency and their design principles in five departments including the construction management department across the College of Engineering at a northwest metropolitan university. The project also aims to improve engineering students' ability to create sustainable and resilient engineering designs. The current study focuses on the student's knowledge and attitudes toward sustainability and resilience before and after they were introduced to such concepts in the construction management curriculum.

The research team provided a stand-alone template module on sustainability and resilience and their design principles in engineering, and shared with the faculty members in the College of Engineering. The research team also provided consulting for faculty members in adapting the stand-alone module into one of the courses he/she chose as needed.

Sustainability and resilience were integrated into two construction management courses (Introduction to Construction Management and Mechanical and Electrical Installations) by two faculty members via embedding both concepts and their design principles into existing course content. The Introduction to Construction Management is an introductory course covering fundamental and evolving processes and practices of the construction process. The Mechanical and Electrical Installations course was designed to introduce students to construction principles and practices with

Mechanical, Electrical, and Plumbing systems and guide them how to analyze the value of the systems. The introduction of sustainability was centered on its three Ps principles, the people, planet and profit. The introduction of resilience was centered on its design principles of robustness, rapidity, redundancy, and resourcefulness. Both courses also focused on the use of environmentally responsible and resource-efficient practices and resilient practices into construction projects that can benefit the environment, economy, and society.

V. METHOD

Pre- and post-survey regarding students' knowledge and attitude toward sustainability as well as their knowledge of resilience were administered before and after students were introduced to such concepts in two construction and management courses. Some of the survey questions were adapted from a previous project that aimed to implement sustainability and resilience into the civil engineering curriculum (NSF award: 1612405). Some survey questions were adapted from the tools for assessing sustainable development in Engineering Education proposed by Sánchez-Carracedo and colleagues [13]. Finally, some survey questions were designed based on the learning objectives for sustainability and resilience according to ABET [14]. Specifically, the survey included six questions on the knowledge of sustainability, four questions on the attitudes of sustainability, and 11 questions on the knowledge of resilience.

Forty students from two construction management courses completed both the pre- and post- survey. All the participants were introduced to the concepts of sustainability and resilience for the first time in a formal manner. 82% of the participants were male and 18% of the participants were female. 85% of the participants were white, a few (four) were Asian, one was native Hawaiian or Pacific Islander, and one was self-identified as other. 29 participants were Construction Management majors and 10 were Civil Engineering majors, and one other. The majority participants (35 out of 40) reported that they had not even heard about sustainability and resilience prior to their course. Sixty-five percent of the participants were either freshman or sophomore. Since students in both courses were introduced to sustainability and resilience for the first time, we pooled the data from two courses for statistical data analysis. The following presents the results.

VI. RESULTS

The survey data showed that students' knowledge of sustainability has been significantly improved (p =.039) after they were introduced to sustainability and its design principles (Table I). However, there was no significant change in students' attitudes toward sustainability after the instruction of such concept (p=.347).

TABLE I. STUDENT KNOWLEDGE OF AND ATTITUDE TOWARDS SUSTAINABILITY

	Mean Diff.	Std. Dev.	Std. Error Mean	t	df	Sig. (2-tailed)
Pre- & Post-Knowledge of Sustainability	-1.000	2.961	.468	-2.136	39	.039
Pre- & Post-Attitude toward Sustainability	.4000	2.658	.420	.952	39	.347

A further look at the student's attitude toward sustainability showed that students had a very positive attitude toward sustainability (M=4.11 on a 5-level Likert scale with 1 being the lowest and 5 being the highest) in the pre-survey. Most of them had agreed on the importance of having the design principles of sustainability guide the solutions to social and environmental problems. A one sample t test with the average of participating students' pre-survey attitude (M=4.1) toward sustainability against the default average attitude (M=2.5) based on the 5-level Likert scale showed that there is a significant difference (p< .001) (Table II), which showed that the students' attitude toward sustainability in the pre-survey was already very positive. The students' very positive attitude toward sustainability in the pre-survey did not leave much room for improvement in the post-survey.

TABLE II. ONE-SAMPLE TEST ON PARTICIPATING STUDENTS' PRE-ATTITUDE TOWARD SUSTAINABILITY

	Test Value = 2.5 based on a 5-level Likert scale			
	Mean Diff.	t	df	Sig. (2-tailed)
Pre- attitude toward Sustainability	1.6125	17.102	39	.000

There was no significant improvement regarding students' knowledge of resilience in the post-survey (p=.835) (Table III) based on the students' responses to the 11 knowledge questions for resilience.

TABLE III. STUDENT KNOWLEDGE OF RESILIENCE

	Mean Diff.	Std. Dev.	Std. Error Mean	t	df	Sig. (2-tailed)
Pre- & Post-Knowledge of Resilience	.100	3.080	.477	.209	39	.835

VII. DISCUSSION

The instruction of sustainability and its design principles improved students' knowledge and understanding of the concept, which is consistent with previous research [3]. It was interesting that the participating students had a very positive attitude toward sustainability prior to being introduced to sustainability (Table II) although most of them had not even heard about the concept. This finding may have resulted from the fact that most students were construction management majors or civil engineering majors who had on average a better awareness of and were more inclined to believe in sustainability. However, further research on sustainability

comparing construction management and civil engineering majors with other majors is needed to investigate this "inclination".

It was also interesting to see that there was no significant improvement in the pre- and post- knowledge of participants regarding resilience. Resilience was less discussed and introduced to students in engineering compared to the concept of sustainability in both courses. On another note, sustainability generally appears more in public discourse than resilience does. Sustainability, even when it had not been previously introduced into the curriculum, it is discussed in other areas or specifically emphasized in policies guiding the field of civil engineering and construction management. It may be not sufficient to introduce a relatively new concept which is less discussed on general, such as resilience, in one course, and expect the significant impact of the one-time introduction. Therefore, sustainability and resilience should be integrated in multiple courses to improve students' knowledge and understanding of such concepts.

Generally speaking, a more positive attitude toward a concept leads to better learning outcomes. We were not sure if the students had a less positive attitude toward resilience compared with that of the sustainability, which might have impacted students' knowledge after they were introduced to resilience. However, we did not collect students' attitude toward resilience, which is a limitation of this study. Future studies need to include the data collection on students' attitude toward resilience as well as student's knowledge in the same study. In addition, the questions measuring students' attitudes based on self-reported responses which may have not truly reflected the students' attitudes toward sustainability. Future studies using different measures of attitudes toward sustainability are recommended.

REFERENCES

[1] UNESCO. (2005). "United Nations decade of education for sustainable development (2005-2014): International implementation scheme". Available at: https://unesdoc.unesco.org/ark:/48223/pf0000148654

[2] Ruiz-Mallén, I. and Heras, M. (2020). "What sustainability? Higher education institutions' pathways to reach the agenda 2030 goals". Sustainability, Vol. 12 No. 4, pp.: 1290.

[3] Ashraf, MW. and Alanezi, F. (2020). "Incorporation of sustainability concepts into the engineering core program by adopting a micro curriculum approach: A case study in Saudi Arabia". Sustainability, Vol.12 No. 7, pp. 2901-2912.

[4] McWhirter, N. and Shealy, T. (2020). "Case-based flipped classroom approach to teach sustainable infrastructure and decision-making". International Journal of Construction Education and Research, Vol. 16 No. 1, pp. 3–23. Available at: https://doi.org/10.1080/15578771.2018.1487892

[5] Al-Bahi, AM. and Solimán, A.Y. (2016). "Designing a resilience module in an introductory engineering design course for freshmen", IEEE Global Engineering Education Conference 2016, pp. 772-779.

[6] Milcarek, R. J., Garrett, M. J., Falkenstein-Smith, R. L. and Ahn, J. (2016, April). "The development and evolution of the engineering design process in engineering education: From sustainability towards resilience". [Paper presentation] 2016 ASEE St. Lawrence Section Conference. Ithaca, NY.

[7] Thürer, M., Tomašević, I., Stevenson, M., Qu, T. and Huisingh, D. (2018). "A systematic review of the literature on integrating sustainability into engineering curricula". Journal of Cleaner Production, Vol. 181, pp. 608–617.

[8] Dancz, C., Ketchman, K., Burke, R., Hottle, T., Parrish, K., Bilec, M. and Landis, A. (2017). "Utilizing civil engineering senior design capstone projects to evaluate students' sustainability education across engineering curriculum". AEE Journal, Vol. 6, pp.1–27.

[9] United Nations General Assembly. (1987). "Development and international economic co-operation: Environment–Report of the world commission on environment and development". Forty-second session. A/42/427. Available at: https://digitallibrary.un.org/record/139811?ln=en

[10] Penn, M. R. and MFields, K. M. (2017). "A new framework for teaching the triple bottom line: The sustainability triangle and the sustainability index". 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. Available at: https://doi.org/10.18260/1-2--27491

[11] Bodin, P., and Wiman, B., (2004). Resilience and other stability concepts in ecology: notes on their origin, validity, and usefulness. ESS Bulletin, 2 (2), 33–43.

[12] Bruneau, M. and Reinhorn, A. (2007), "Exploring the concept of seismic resilience for acute care facilities". Earthquake Spectra, Vol. 23 No. 1, pp. 41–62.

[13] Sánchez-Carracedo, F., and López, D. (2021). "A Service-Learning Based Computers Reuse Program". Sustainability 2021, 13, 7785. https://doi.org/10.3390/su13147785

[14] ABET. (2020), "Criteria for accrediting engineering programs, 2020–2021", available at: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/