Leveraging an Active-Learning Approach through Online Courses to Foster Sustainable, Equitable, and Resilient Infrastructure Concepts

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Abstract

This study aims to position active learning as a potential approach for teaching equitable resilience of infrastructure projects through online courses within construction curricula. Exposure to active learning methods can significantly enhance the problem-solving abilities of construction management (CM) students, preparing them for complex technical challenges in their future careers. Additionally, such interactive teaching strategies can help students retain information about advanced and practical concepts. However, in online learning environments, keeping students engaged poses a unique challenge. Unlike in-person classes, online courses present a distinct challenge because the only means of social interaction between the instructor and the student is through the Internet. This paper explores active learning strategies that can be incorporated into the design of online learning courses to foster student engagement in teaching sustainable, equitable, and resilient infrastructure (SERI) concepts. The objective of this study is to assess the efficacy of the active learning approach in improving students' knowledge and awareness in online settings. To achieve this objective, this study designed an active learning module that included various tasks for the participants. At first, students were instructed to watch a video that addressed current inequality in resilient infrastructure projects. Subsequently, open-ended questions were presented to the students along with instructions to respond via the Canvas online platform. Lastly, the students were requested to offer constructive feedback on a minimum of two classmates' responses that are available on Canvas. Pre- and post-activity surveys were conducted with 32 CM students for data collection. The findings highlighted that the active learning approach was effective in improving the participants' knowledge in online class settings. Moreover, most of the participants shared positive feedback about the activity and supported utilizing such active learning techniques in online courses. This research underscores the potential of active learning methods in teaching concepts that are relevant to students' future careers through online courses thus empowering future professionals in the future career.

Introduction and Background

Online learning pedagogy offers students an alternative to traditional face-to-face courses, allowing them to progress through the material at their own pace and have a more accurate perception of the effectiveness of their learning [1]. However, engaging students in online courses presents unique challenges compared to traditional face-to-face classrooms. Online course delivery requires upfront course design, effective time and resource management by both students and faculty and various methods to foster communication and interaction [2]. Additionally, implementing teaching tools effectively can be a hurdle for faculty. Active learning approaches can mitigate these issues by encouraging active participation from the learners. Active learning, often linked with traditional in-person classes, can be successfully integrated into online or blended learning environments through various strategies [3]. These include structured discussions, group

tasks, and nurturing a collaborative environment beneficial to learning. Incorporating active learning into discussions, assignments, and assessments can support effective student engagement in online or blended courses.

Active learning can be defined as the process of "seeking new information, organizing it in a way that is meaningful, and having the chance to explain to others" [4]. Studies have consistently demonstrated that the implementation of active learning methods not only enhances students' learning outcomes but also positively influences their attitudes toward learning [5]. Despite the proven benefits, many faculty members encounter challenges when integrating active learning into their courses. Successful incorporation of active learning requires experimentation and exploration of teaching and learning methods, particularly in the context of online education [3]. While this may demand additional effort, it is a necessary endeavor to ensure students are actively engaged in their learning experiences, regardless of the instructional medium. Effective implementation of active learning strategies throughout a course has repeatedly demonstrated its ability to promote student engagement and significantly impact student learning.

The effectiveness of an active learning method varies from many methods that are often used in online settings due to its focus on engaging learners through interactive and participatory activities. Active learning requires students to actively participate in the learning process by engaging in discussions, problem-solving activities, and collaborative projects, as opposed to passive learning methods where students passively receive information [6]. This hands-on approach encourages deeper understanding, critical thinking, and retention of knowledge [7]. Active learning approaches also promote interaction and collaboration among learners, cultivating a sense of community and peer-to-peer learning by embracing various active learning strategies such as group work, case studies, simulations, and role-playing exercises [8]. Moreover, such teaching methods often incorporate real-world applications and practical exercises, allowing students to apply theoretical concepts to real-life scenarios. Additionally, active learning methods offer immediate feedback and assessment opportunities, enabling instructors to analyze student progress and address any misunderstandings in real time [9].

This study leveraged active learning strategies to deliver sustainability and resilience education in online settings. Literature has suggested that learner-centered online learning can be particularly effective for sustainable development education [10]. Several studies have highlighted the advantages of online learning environments, including a student-centered, self-regulated learning process [11], lower educational costs, flexibility in time and location, improved understanding of course material [2], and a more accurate perception of the effectiveness of one's learning [12]. Azeiteiro [13] specifically observed that students in online courses demonstrated high motivation, satisfaction, and successful attainment of learning outcomes. However, student engagement is a challenge not only in traditional face-to-face classrooms but arguably more so in online courses. The delivery of online courses introduces additional hurdles, such as the need for course design before material delivery, effective time and resource management by both students and faculty, differences in methods for encouraging student communication, and challenges in implementing teaching tools. However, active learning strategies can address these concerns, fostering student participation in the online course content [3]. Although active learning is not commonly associated with online or blended learning

environments, incorporating well-conceived discussions, group work, and creating a collaborative learning environment can effectively promote active learning in non-face-to-face settings. It is crucial to integrate active learning throughout major course components, including discussions, assignments, and assessments, to enhance student engagement significantly.

This research aims to investigate the effectiveness of active learning strategies in online class settings. To achieve, this goal this study leveraged a unique strategy to create an active learning environment in an online course in order to cultivate concepts related to sustainable, equitable, and resilient infrastructure (SERI). Although previous literature has studied sustainability education in online settings [14]–[16], it is evident that the social aspect of sustainability and resilience is currently underrepresented in sustainability curricula [17]. This study designed a stand-alone module which included watching a video related to the sustainable, resilient, and equitable infrastructure topics and then participating in a discussion session. The discussion session included students responding to open-ended questions along with offering constructive feedback on a minimum of two classmates' responses. This study used a Canvas discussion forum for the discussion session which allowed the registered students to provide feedback on the open-ended questions of their peers. This study adopted a discussion approach using online platforms to promote student engagement and foster critical thinking skills among the participants. Literature has highlighted the benefits of discussion approaches including improving communication skills [18], enhancing student learning [19], and providing an avenue for active learning in online class settings. In the context of online courses, discussions hold significant importance and can heavily influence the course's success [20]. Establishing an environment that facilitates high-quality online discussions is critical for the effectiveness of online courses. Although discussions in face-to-face classrooms may not seamlessly translate to an online course, online discussions offer advantages such as convenience, additional time for reflection, increased participation, a sense of community [21], and the opportunity for instructors to interact more extensively with students without the time constraints of face-to-face classes.

Methodology

This section explains the active learning module that teaches construction students about SERI concepts in an online class setting. The module was implemented in a cross-listed online course. The module aims to improve the construction management (CM) students' understanding and awareness of various infrastructure resilience inequity issues as well as to guide them to address these issues during infrastructure project developments. Figure 1 presents the research overview of the study.

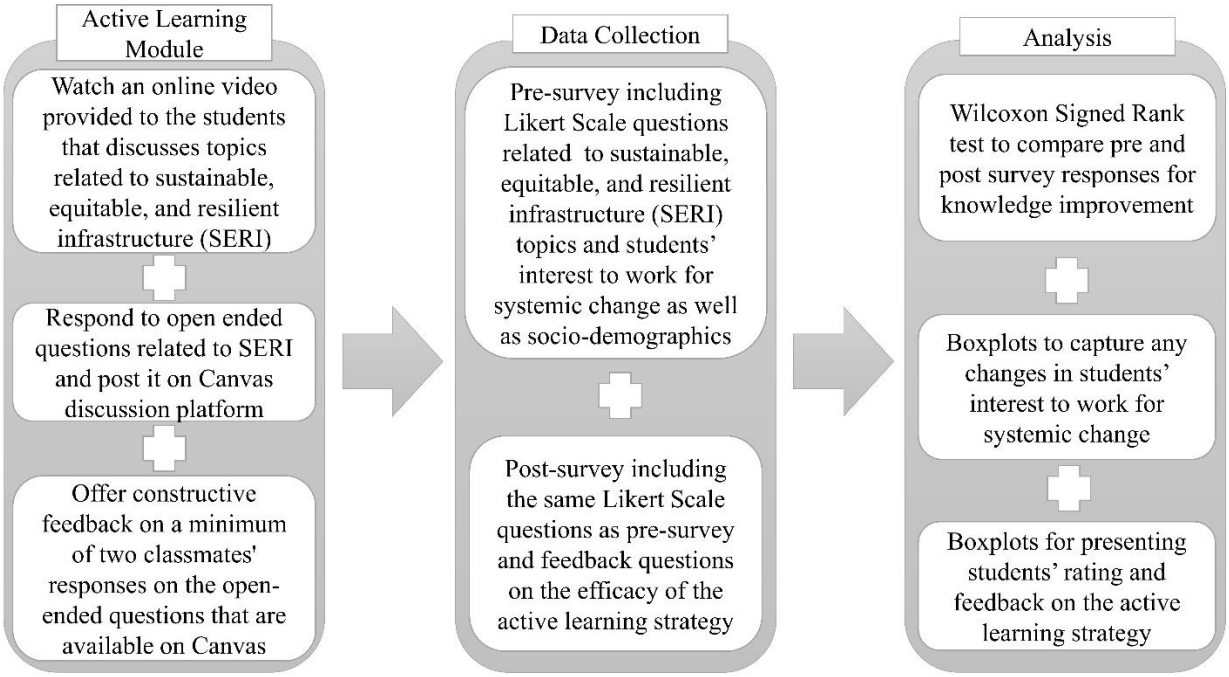

Figure 1. Research Overview

Thirty-two CM students participated in this study. At first, the students were instructed to complete a pre-survey before the training. The pre-survey included socio-demographic questions as well as questions assessing the students' existing knowledge about SERI topics. Then, the students were instructed to watch a video and complete an assignment. The assignment included responding to two open-ended questions: 1. Based on your experiences and knowledge, what recommendations do you have for incorporating equity in future resilient infrastructure developments? And 2. Are there any specific policies or practices you believe should be implemented to ensure equity in infrastructure projects? The purpose of the assignment was to ensure that the students watched the whole video. The assignment was not part of the analysis of this study. Additionally, the students were requested to offer constructive feedback on a minimum of two classmates' responses to these open-ended questions that are available on the Canvas discussion platform. The purpose of the assignment and the open-ended question was to cultivate student engagement in such online settings. After watching the video and completing the assignment, the students were allowed to participate in a post-survey that captured their knowledge improvement about tackling infrastructure resilience inequity challenges, their change in perception about systemic change, and their feedback about the active learning module. The online video was collected from the Institute of Sustainable Infrastructure (ISI) website which introduced the CM students to various SERI topics such as environmental racism, gentrification, environmental justice, social equity, and equitable resilience. The criteria and considerations involved in the selection process of the video were that the video should explain existing infrastructure inequity issues for the underserved population, provide practical examples of equity and resilience, and discuss how to address these issues.

Survey data was collected for the current study through convenience sampling. Participants in this method were chosen according to their convenience and accessibility. In particular, those who took part in the study were registered students for the fall semester of 2023 in the Construction Management (CM) program's cross-listed Sustainable Approach to Construction online course. An online surveying tool, Qualtrics, was used to prepare and distribute the survey among the CM students. The pre-survey included five-point Likert scale questions and socio-demographics questions. The Likert scale questions focused on recording data related to (i) students' knowledge improvement about various infrastructure inequity scenarios, and (ii) students' interest in working for systemic change to address inequity in resilient infrastructure developments. The demographic questions recorded the participants' social and educational backgrounds. The post-survey included the same Likert scale questions as the pre-survey to compare the responses and assess knowledge improvements through the module. Additionally, the post-survey included Likert scale questions to reflect students' feedback on the efficacy of the training in improving their understanding of SERI concepts.

The pre-and post-survey data were analyzed using both quantitative and qualitative methods. The study utilized the Wilcoxon signed rank test to compare students' understanding of SERI concepts before and after the training using the Likert-scale data. The Wilcoxon Signed-Rank test is a nonparametric test used for paired data (i.e., pre- and post-surveys). This test is implemented "to test the hypothesis that the median difference between the absolute values of positive and negative paired differences is 0" [22]. The Wilcoxon signed-rank test was performed using SPSS with a 95 percent confidence interval and a maximum targeted P-value of 0.05. Additionally, the study utilized R studio to develop boxplots representing the pre- and post-survey Likert scale data to visualize the overall changes in the student's interest in working towards systemic change. Lastly, the authors assessed the student's responses to the Likert scale question about the efficacy of the module and developed a boxplot demonstrating their feedback responses.

Results

This section presents the results that determine: (1) the knowledge improvement of the CM students on SERI topics achieved through the active learning module to teach in online class settings; (2) the perception of CM students about their interest in systemic change to address inequity in infrastructure resilience; and (3) the student's feedback on the efficacy of the module. The participants in this research included 32 students primarily from construction majors along with additional representation from civil engineering, and architecture majors. Among the participants, 62.5 percent identified themselves as Hispanic, whereas 37.5 percent were non-Hispanic students. Moreover, 6 percent of the students were identified as African American, 62.5 percent as white, 16 percent as Asian, 3 percent as American Indian, 3 percent as members of more than one ethnic group, and 9 percent as other races. Figure 2 presents the socio-demographic background of the participants.

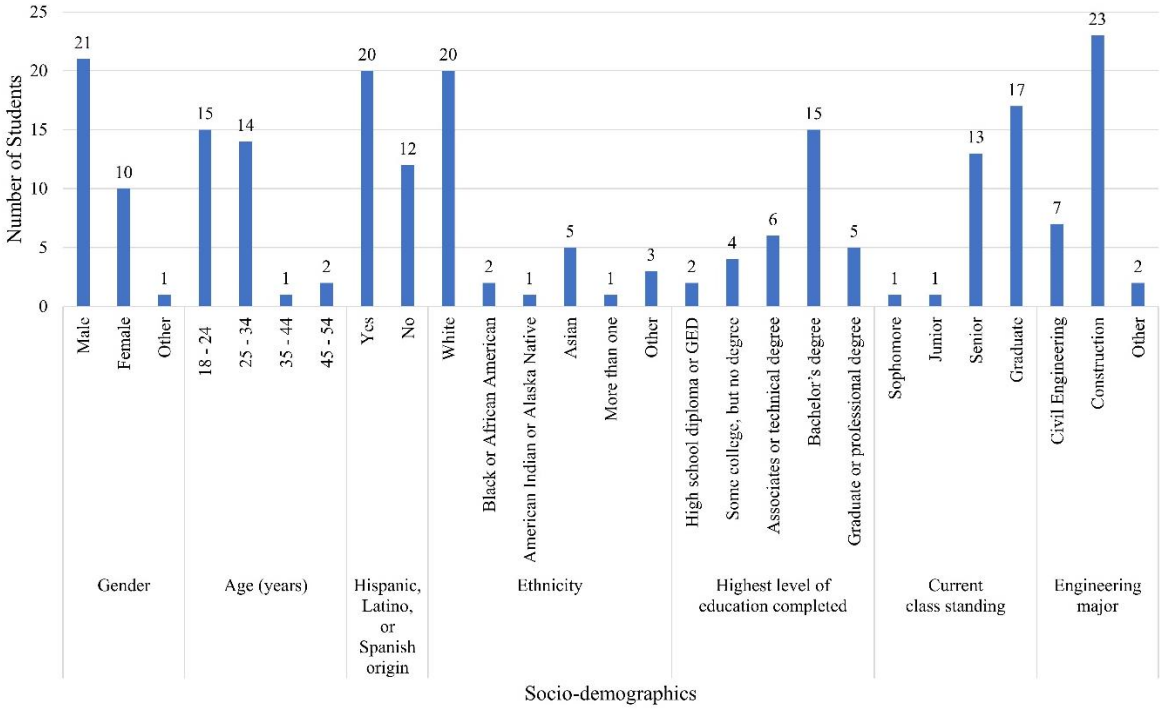

Figure 2: CM students' socio-demographic background information (n=32)

To identify the effectiveness of the active learning module, a Wilcoxon Signed-Rank test was conducted using the pre- and post-survey Likert scale data. The findings from the analysis shown in Table 1 list the absolute mean, mean difference, standard deviation values, and the minimum and maximum scores for each of the variables, during the pre-and post-surveys. Additionally, as shown in Table 2, the variables with a p-value of less than 0.05 are considered statistically significant so the null hypothesis can be rejected. The absolute mean difference between the pre- and post-survey responses showed a significant improvement in students' knowledge and skills. The obtained results indicated that the active learning module was effective in teaching SERI topics in an online setting in terms of (1) improving the student's ability to provide examples of resilient infrastructure projects that have successfully addressed societal inequalities in vulnerable communities; (2) increasing the awareness about civil engineering/construction management program covered topics related to equity in developing resilient infrastructure; and (3) encouraging students to study about case studies or projects that focus on ensuring equity and social justice in resilient infrastructure systems. Regarding variables 1, 2, 3, 4, 5, and 9, results indicate a p-value of more than 0.05, meaning that the module did not change the student's perspective significantly in those aspects.

Table 1. Descriptive statistics of Wilcoxon signed-rank test (n=32)

Variable ID	Variables	Mean	Absolute Mean Difference	Std. Deviation	Minimum	Maximum
1 - Pre		3.81	0.1	0.998	2	5

1 - Post	Awareness of communities within their region that are more vulnerable to natural disasters and climate change impacts	3.91		0.893	2	5
2 - Pre	Awareness of specific social or economic factors that make certain communities more susceptible to infrastructure-related vulnerabilities	3.56	0.22	1.014	2	5
2 - Post		3.78		0.906	2	5
3 - Pre	Awareness of social injustices and inequities within infrastructure projects?	3.59	0.19	1.073	1	5
3 - Post		3.78		0.87	2	5
4 - Pre	Situations of social inequalities influencing engineering decisions during studies or work experiences	3.06	0.38	1.318	1	5
4 - Post		3.44		1.134	1	5
5 - Pre	Ability to define resilient infrastructure in the context of natural disasters	3.44	0.37	1.294	1	5
5 - Post		3.81		0.896	2	5
6 - Pre	Ability to provide examples of resilient infrastructure projects that have successfully addressed societal inequalities in vulnerable communities.	3.12	0.76	1.008	1	5
6 - Post		3.88		0.907	2	5
7 - Pre	Knowledge of civil engineering/construction management program covered topics related to equity in developing resilient infrastructure	3.25	0.34	1.016	2	5
7 - Post		3.59		0.798	2	5
8 - Pre	Studying about case studies or projects that focus on ensuring equity and social justice in resilient infrastructure systems	2.81	0.75	1.203	1	5
8 - Post		3.56		1.105	1	5
9 - Pre		3.97	0.06	0.999	2	5

9 - Post	Importance of considering social equity in the planning and implementation of resilient infrastructure projects?	4.03		1.062	1	5
10 - Pre	Awareness about the lack of access to transportation affects the overall resilience of a community during and after a disaster?	4.13	-0.07	0.907	2	5
10 - Post		4.06		0.878	2	5

Table 2. Wilcoxon signed-rank test statistics results

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9
Z	-0.661	-1.091	-0.753	-1.350	-1.522	-3.305	-2.057	-3.088	-.551
Asymp. Sig. (2-tailed)	0.509	0.275	0.452	0.177	0.128	<.001	0.04	0.002	0.582
p-value	>0.05	>0.05	>0.05	>0.05	>0.05	<0.05	<0.05	<0.05	>0.05

Additionally, students were allowed to rate their level of interest from 1 to 5 (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly) to work towards systemic change in order to address inequity in developing infrastructure sustainability and resilience. Boxplots were created using R-Studio to showcase the students' level of interest, as shown in Figure 3. It can be inferred from the boxplot that before implementing the module the median value was 3 which increased in the post survey responses to 3.5. This indicates that the module was effective in motivating the students to work towards diminishing inequity and creating systemic change in infrastructure development.

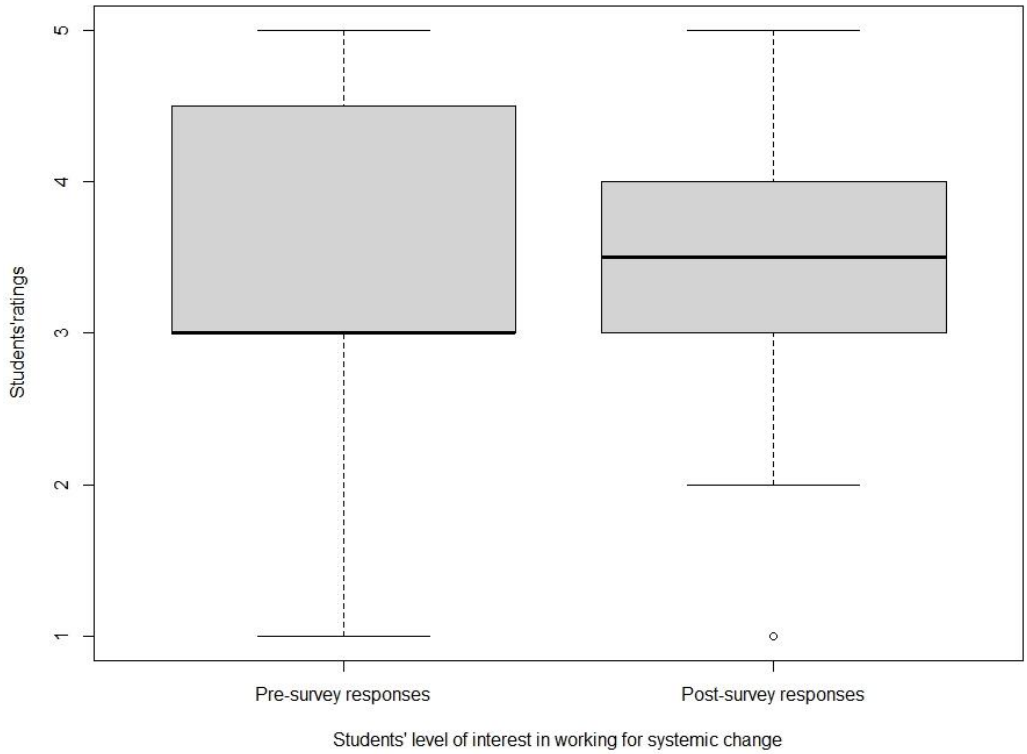

Figure 3: Boxplots of the students' level of interest in working for systemic change. (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly)

In order to capture students' feedback on the effectiveness of the active learning module in teaching SERI topics, the students were asked to rate evaluation statements. The questionnaire presented the students with seven evaluation statements and asked them to provide their opinions on a five-point Likert scale to evaluate the module. Figure 4 presents the boxplots which indicate that all the statements have a median value of 4 inferring that the module greatly helped the students in improving their knowledge about SERI topics in an online setting. Although most of the statements reflected the minimum value of 3 signifying moderate agreement, the statement related to engagement with the activity had a minimum value of 2 suggesting that certain students may not have felt sufficiently engaged during the activity.

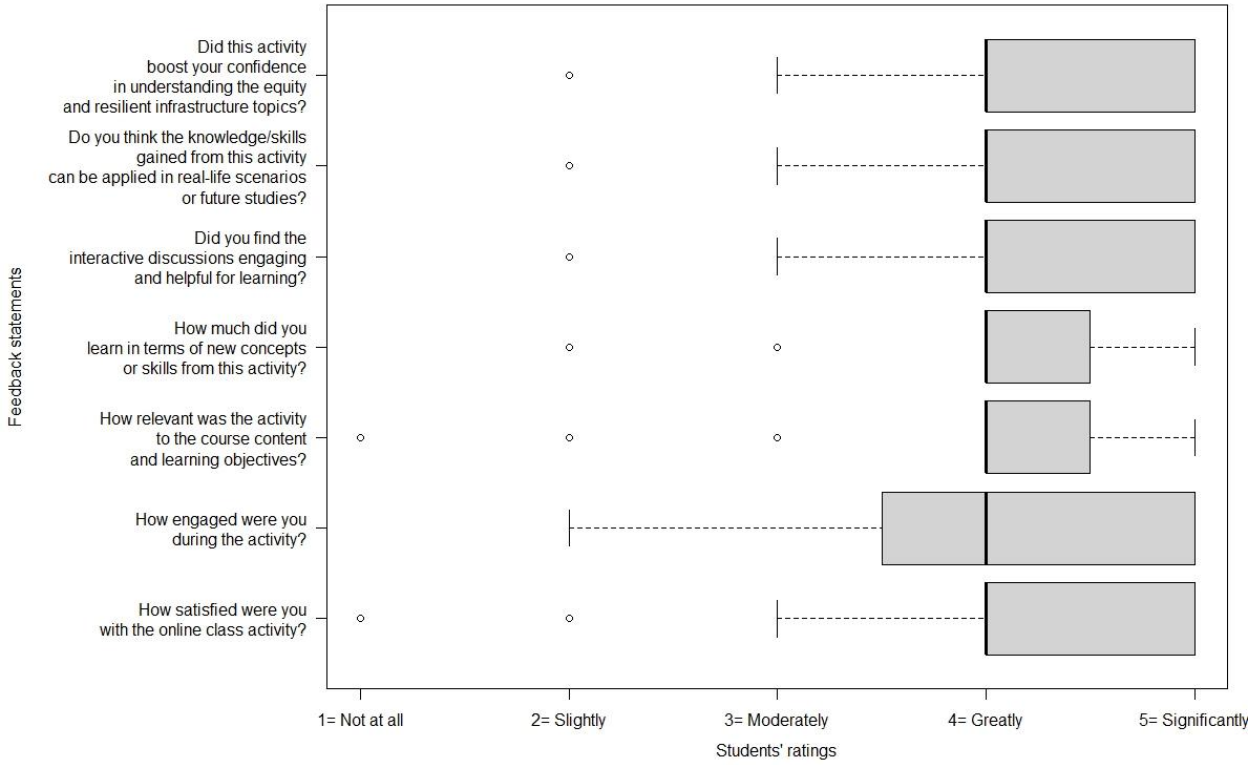

Figure 4: Boxplots of the students' feedback on the training. (1= None at all, 2= Slightly, 3= Moderately, 4= Greatly, 5= Significantly)

Limitations and Future Works

This research acknowledges some limitations. The survey responses might be subjective to self-assessment and biases. Additionally, convenience sampling may impose some restrictions on how broadly the results can be applied because it does not guarantee that the sample is representative of the total population but rather only includes those who were most easily accessible or available to participate in the study. Moreover, due to resource constraints, the study used a small sample size for data collection. Therefore, the findings may not be fully representative of the broader population. Caution should be exercised when interpreting and extrapolating the findings. Future research can focus on recruiting a larger sample from different class settings such as hybrid format classes to confirm and extend the current findings. Additionally, future research should prioritize the assessment and characterization of participant biases to enhance the robustness and reliability of study outcomes.

Conclusion

Integrating active learning into course material is crucial to engaging students, regardless of the environment. However, because of the unique nature and challenges of online courses, unique approaches to active learning are needed to be explored. This research implemented an active learning module within a cross-listed sustainability class in an online setting. This study intended to tackle the challenge of student engagement in an online class setting by providing a discussion platform where students could offer constructive feedback to their peers. Students' experiences

and feedback shared through the survey indicated that the module successfully instigated students' interest and helped expand their understanding of complex sustainability issues and social equity topics. The pre and post-survey responses highlighted that the module improved students' comprehension of SERI topics. Thus, the module fostered a deeper understanding of complex sustainability topics among the participants and enhanced students' motivation to work for systemic change. This study underlines the significance of active learning mechanisms that can be used in the design of an online learning environment to potentially foster a high level of student engagement. With the increasing participation of students in online courses, it is hoped that the utilization of these methods will become more prominent in online course delivery to tackle the challenges faced in developing and delivering effective online courses.

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