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A PROBLEM-BASED LEARNING APPROACH TO DEVELOP MINORITY STUDENTS' SUSTAINABILITY KNOWLEDGE AND PROFESSIONAL SKILLS

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Abstract

The motivation of this study is to position problem-based learning (PBL) as an effective method to teach infrastructure sustainability as well as enhance the professional development of minority students in engineering. Indeed, the minority students' exposure to active learning methods such as problem-based learning (PBL) can effectively foster their capability to deal with open-ended technical problems in their future careers. Additionally, the interactive nature of such methods can facilitate knowledge retention of emerging and effective sustainability concepts. This study highlights how the PBL technique can develop soft skills during sustainability education to Architecture, Engineering, and Construction (AEC) students at a minority-serving institution as an effort to promote professional skills of underrepresented groups, i.e., women of color, Latinos/Hispanics in a classroom. This study designed and implemented a PBL activity in a cross-listed Sustainable Approach to Construction course which introduced the students to: (1) sustainable infrastructure and Front-End Planning (FEP) techniques; and (2) how they complement each other to build sustainable infrastructure systems effectively. Sustainable infrastructure systems are critical to reducing social, economic, and environmental impacts on the built environment and FEP can complement building infrastructure systems sustainably by providing effective planning, better scope definition, and improved decision-making. A post-activity survey allowed the 35 AEC students to evaluate the improvement of their sustainability knowledge as well as multiple professional skills including leadership, communication, critical thinking ability, working in teams, and project management through the activity. The results indicated that most of the students including minorities had substantial improvement in their professional skills as well as advanced their knowledge in both areas of infrastructure sustainability and Front-End Planning. Furthermore, the analysis of the open-ended questions revealed that the students valued the PBL method because it offers interactivity, teamwork, an interdisciplinary knowledge-sharing platform, and the ability to simulate a real-life work environment. The findings of this study reveal the positive outcome of the implemented approach by integrating PBL activity in sustainability education for minority students from AEC majors. This method conveys an effective scheme to foster infrastructure sustainability concepts while nurturing multiple professional skills of minority students, particularly the underrepresented groups to better prepare them for the competitive real world.

Keywords: Front-End Planning, Sustainable Infrastructure, Infrastructure Education, Minority, Professional Development

Introduction and Background

Infrastructure construction projects often use unsustainable materials leading to various environmental challenges to the built environment and the surrounding community, thus contributing to the causes of global warming and climate change. Sustainable construction

focuses on addressing these challenges and works towards alleviating the associated environmental impacts as well as providing human comfort and quality. Sustainable design improves the built environment's performance through balancing the environmental, social, and economic impacts of construction projects known as the Triple Bottom Line [1], [2]. The uncontrolled use of limited natural resources and rapid community development threatens the Triple Bottom Line [3], indicating the necessity for building sustainable infrastructure projects [4], [5]. Thus, with the increasing demand for sustainable developments, construction education must provide effective platforms for future professionals to learn about how to manage the new design, construction, and operational challenges associated with sustainability, particularly for infrastructure projects.

Several sustainability rating systems have emerged to provide guidelines to build infrastructures as sustainable. These rating systems were developed as a framework with specific intents and guidelines to incorporate sustainability requirements in the construction project and thus reduce the projects' environmental and social impacts. Literature has highlighted that pursuing the sustainability certification at the early stages of a project can foster effective collaboration between stakeholders thus leading to better project-related decision-making and better project outcomes [6]. This reveals that integrating sustainability at the early stages of a project life cycle, i.e., during pre-project planning or Front-End Planning (FEP) phases, can facilitate achieving desired sustainability goals as well as better project performances including meeting target project cost, schedule, and reduced change orders. Front-End Planning (FEP) is a critical pre-project planning process that focuses on establishing an improved scope definition of a project, thus identifying project-related potential challenges and risks [7]. The FEP phase encompasses the feasibility, concept, and detailed scope of a project extending till the initiation of detailed design and construction activities [8]. Coupling Front-End Planning (FEP) techniques with sustainability practices may provide versatile solutions to build sustainable infrastructure projects with better project outcomes [9]. Therefore, it is necessary to include such techniques for attaining sustainability goals as part of construction teaching efforts thus equipping the future industry professionals with emerging and effective sustainability knowledge and skills.

Given that, the sustainability concepts are becoming more essential in architecture, engineering, and construction (AEC) industries, the American Society for Civil Engineers (ASCE) highlights the significance of integrating sustainability concepts in colleges and universities [10]. Current literature demonstrates the dynamic implementation of sustainability education through various teaching methods. For instance, McWhirter and Shealy [11], [12] have developed a case-based module and a flipped-classroom approach to teach infrastructure sustainability and related decision-making. Elzomor and Parrish [13] introduced civil engineering and construction management students to FEP tools for infrastructure projects and helped the students understand the complexities of real-world construction projects' scope. However, researchers have seldom focused on coupling FEP techniques and sustainability practices for infrastructure projects and how an educational approach involving such techniques and practices can facilitate preparing future workforces.

This study focuses on teaching sustainability knowledge as well as improving the professional skills of the Construction Management (CM) students where the majority of the students are minorities. Underrepresented minority populations in engineering and sciences include women,

African Americans, Hispanics, and Native Americans. The inclusion of the minority population enhances the diversity of a project team. A diverse team of engineers creates heterogeneity within the team thus providing better and more adaptable solutions to various engineering problems. According to Reyes, Anderson-Rowland, and McCartney [14], a diverse engineering workforce that involves women and minorities can be considered more suitable for the global market including customers from around the world. Barry and Walter [15] highlighted the necessity to increase students' experiences with multiple cultures and diverse thinking to build a sense of community and belonging. A diverse team that involves members from different ethnicity, culture, and gender can tackle complex problems having better outcomes [16]. Thus, it is necessary to provide a proper nurturing environment that can allow minority students to improve not only technical skills but also essential non-technical professional skills which will help them thrive in their careers.

Engineering and science students are typically inclined to learn technical concepts lacking the focus on personal and professional preparation which is also necessary to succeed in career and life. According to the latest version of Criteria for Accrediting Engineering programs of ABET [17], many of the stated outcomes are non-technical and can be referred to as soft skills including ethics, teamwork, and communication [18]. Literature has revealed that various innovative active and team-based instructional approaches might be effective to develop such vital engineering skills among the students [19]. Thus studies have focused on implementing problem-based learning in different engineering fields to assess its effectiveness in improving professional skills among engineering students [20]–[25]. However, there is a gap in the literature on developing a framework that can enhance the sustainability knowledge and relevant techniques while improving the professional skills of the CM students including minorities. This study addresses this gap and implements a problem-based learning approach that encompasses disseminating infrastructure sustainability and FEP knowledge to the CM students in a minority-serving institution while boosting the soft skills including team dynamics, communication skills, and problem-solving skills.

This paper presents an integrative learning approach that was implemented within a cross-listed Sustainable Approach to Construction course at a minority-serving institution. The course involved minority students of different ages, educational backgrounds, academic levels, and work environments. Such active learning platforms helped the students to stimulate their intellectual curiosity and critical thinking thus increasing student engagement during their educational experiences. This study develops an integrative framework to teach infrastructure sustainability to minority students while improving their professional skills such as leadership, communication, critical thinking ability, working in teams, and project management through utilizing Problem Based learning (PBL) approach. The PBL approach allows students with open-ended problems and complex questions that can potentially stimulate their problem-solving capacities [26], [27]. Such a method helps students' involvement in problems simulating real-world scenarios and fosters critical thinking to resolve those problems [28].

Methodology

This section presents the implementation of the Problem Based Learning (PBL) activity which involved 35 CM students from the summer 2021 semester. The students were enrolled in a cross-listed Sustainable Approach to Construction course in a minority serving institution. Figure 1 presents the implemented framework which includes a lecture module, instruments, research objectives, and analysis adopted in this study. The lecture module consisted of sustainable infrastructure and FEP topics and how these two concepts complement each other. The instruments included the PBL activity along with pre- and post-survey to assess the improvement of sustainability knowledge as well as professional skills of the CM students and minorities through utilizing statistical tests as well as descriptive analysis.

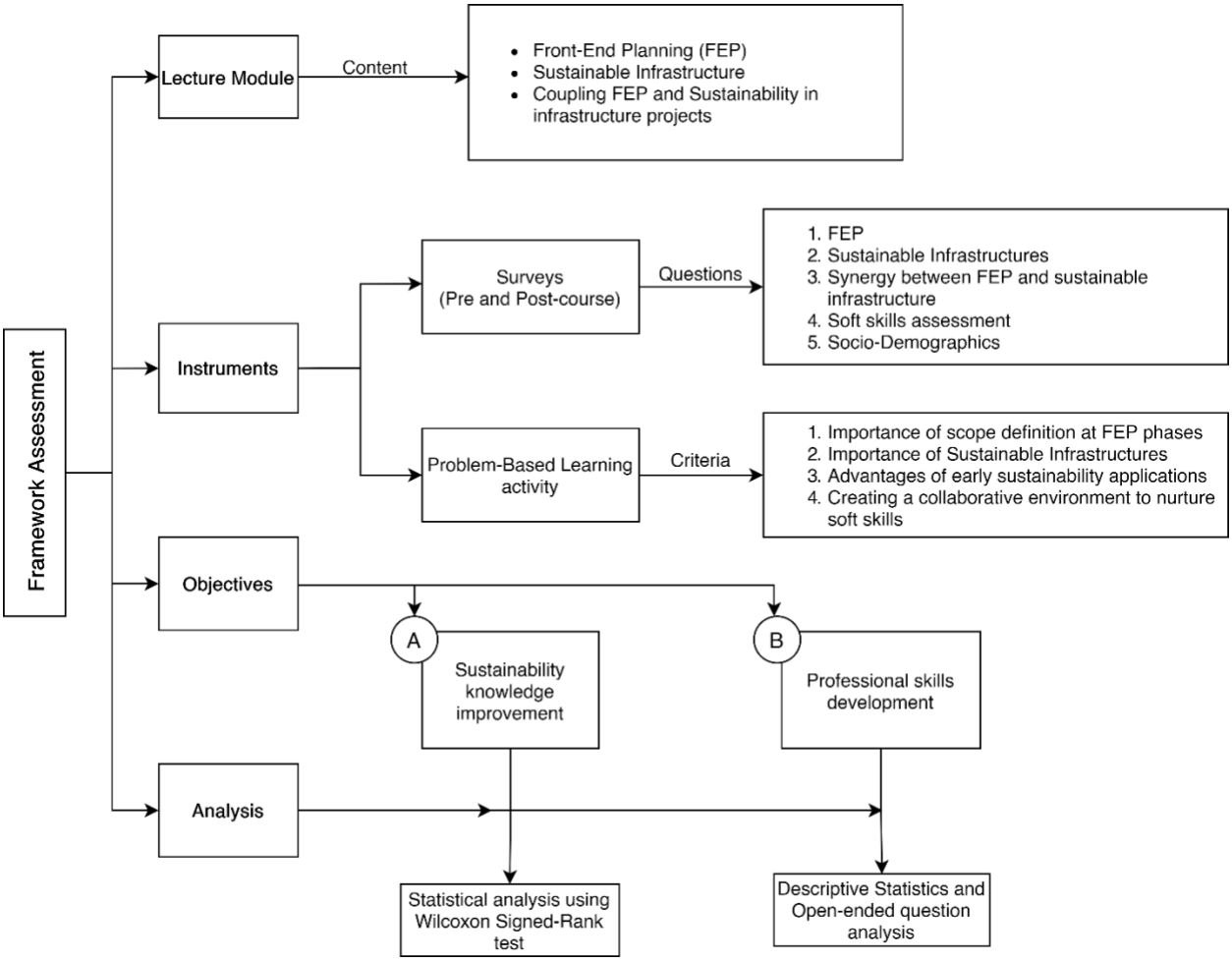

Figure 1. Research Framework

Problem-Based Learning Activity

This study designed a Problem Based Learning (PBL) activity to provide the students with real-life work exposure in sustainable construction as shown in Figure 2. The students were divided into groups of 4-5 members and were assigned to develop a project proposal for a sustainable

transportation infrastructure project. The students were suggested to play various engineering roles such as designers, consultants, engineers, and contractors during the activity. The students were instructed to have a 10-minute discussion session and present their initial proposal within 2 minutes during the following presentation session. The students were provided with feedback from the moderator to include sustainability and FEP topics such as scopes, goals, team roles, risks, and so on during the presentation and were allowed for another 10 minutes discussion session to improve their initial proposal. Finally, the groups were allowed to present their final proposal. The activity ended with an interactive discussion among the students and the moderator on topics like value engineering, local resources, compliance requirements, and so on.

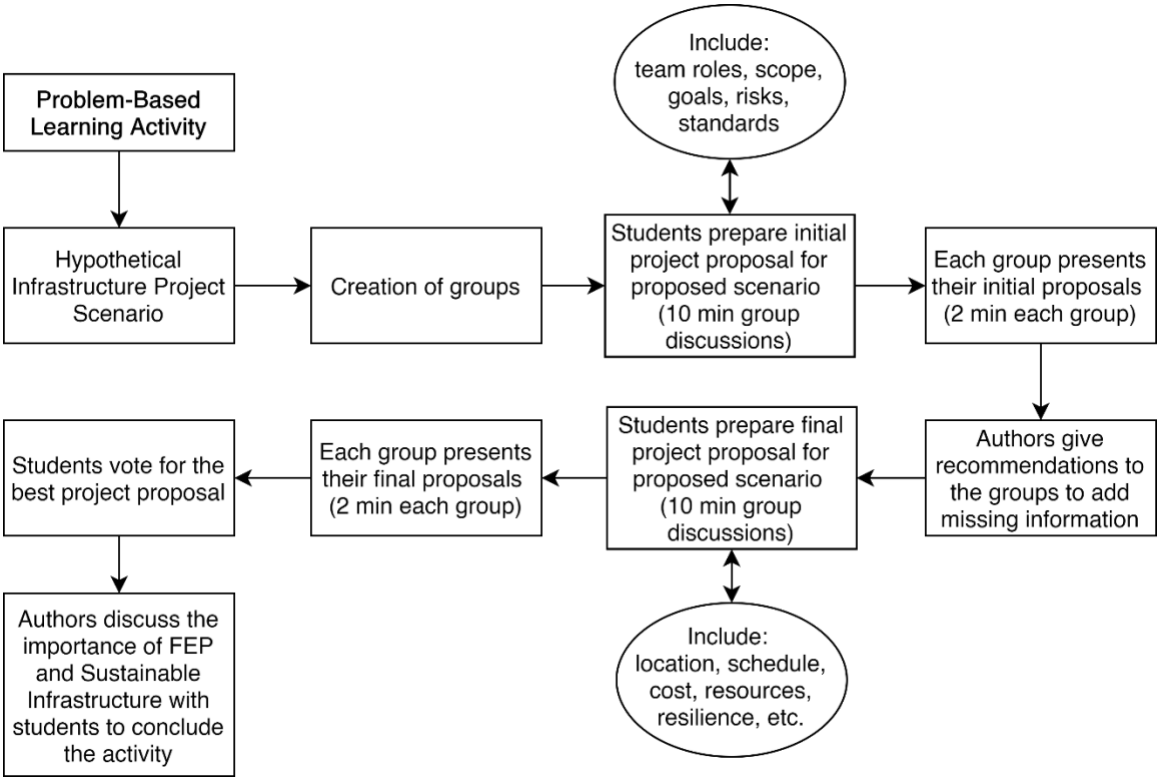

Figure 2. Problem Based Learning (PBL) activity

Survey Design

The pre-and post-course evaluation surveys were designed based on literature review and included several multiple-choice questions to obtain Likert-scale data for evaluating the students' knowledge improvement on the three areas: (1) Front-End Planning (FEP), including scope definition, team alignment, familiarity with FEP tools, and differences between FEP and traditional planning [8], [29]–[32]; (2) Sustainable infrastructure, and the importance of infrastructure projects and sustainable construction to the built environment [4], [13], [33]–[35]; and (3) the possible synergy between FEP and sustainable infrastructure systems along with advantages of stakeholders' early involvement in infrastructure projects [6], [36]–[39]. Additionally, the pre-survey included questions pertaining to students' socio-demographic

profiles, while the post-survey included questions to assess improvement in students' professional skills including leadership, communication, critical thinking ability, working in teams, and project management through the activity. The post-survey also presented students with open-ended questions to highlight their liking and disliking about the activity as well as obtain insight into the impact of the PBL activity. The study conducted a Cronbach Alpha reliability test using SPSS to measure the reliability of the survey instrument.

The study utilized a non-parametric Wilcoxon signed-rank test to compare the pre- and post-survey Likert scale data and assess improvement in the participants' knowledge of sustainability and FEP concepts using SPSS. The Wilcoxon signed-rank test was set to a confidence interval of 95% with the maximum desired P-value of 0.05. This study utilized Wilcoxon signed-rank test, which is a commonly used statistical analysis for comparing non-parametric data obtained from educational interventions [40]. Additionally, this study developed boxplots using the five-point Likert scale data using R-studio to demonstrate how the PBL activity improved the nontechnical professional skills of the CM students including minorities. This study adopted boxplot analysis which is an effective method to demonstrate Likert-scale responses in education research [18]. Moreover, the study analyzed the open-ended questions by examining each response and manually categorizing them to obtain a better insight into the students' likes and dislikes as well as the impact of the implemented PBL activity. The results are presented in detail in the following section.

Results and Analysis

This section presents the analysis and results of this study. The participants targeted through this research are 35 registered students in a cross-listed Sustainable Approach to Construction course at a minority-serving institution. The respondents consisted of 28% female students and 69% male students having various races. This study was conducted in a minority-serving institution thus majority (74%) of the responding students consisted of racial minorities including Hispanics and African Americans as shown in Figure 3. Moreover, the participants were from both undergraduate and graduate-level and almost 46% of the students are currently working in the construction industry.

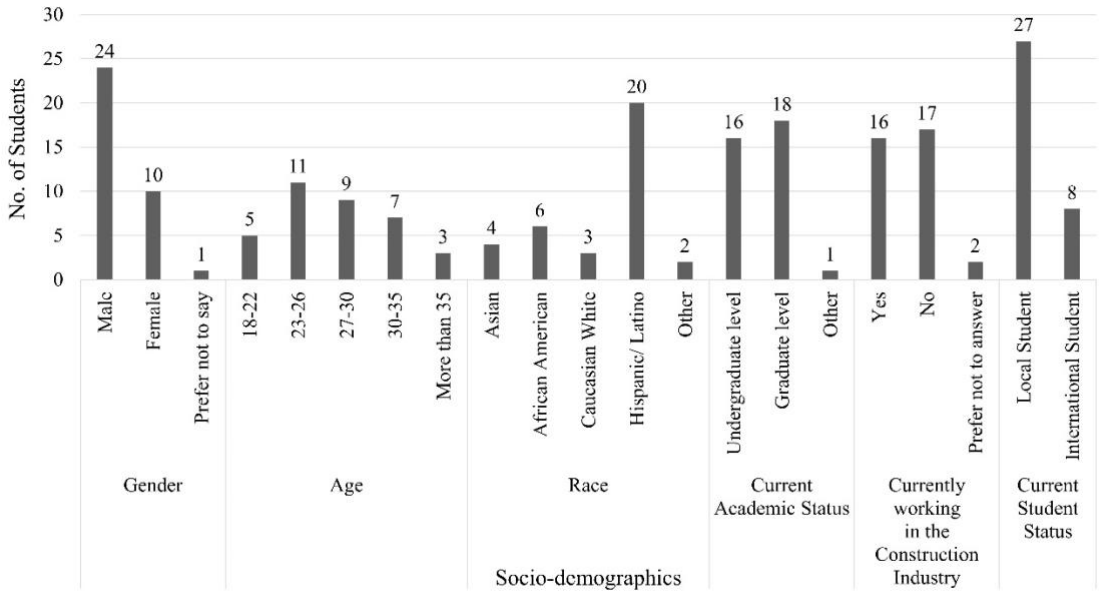

Figure 3. Students' socio-demographic background

Reliability Test

Prior to the detailed analysis, this research conducted a reliability test using Cronbach's Alpha to examine the reliability of the survey questionnaire. Although Cronbach's Alpha ranges between 0 and 1, a value more than 0.7 is considered acceptable [41]. Cronbach's alpha for this study is 0.959 for pre-survey and 0.926 for post-survey, which indicates that the survey data is adequately interrelated and reliable for further analysis [42].

Improving the Students' Sustainability Knowledge

This study utilized the Wilcoxon Signed-Rank test to compare and analyze the pre- and post Likert scale survey data about infrastructure sustainability and FEP knowledge. Table 1 demonstrates the descriptive statistics including the absolute mean difference, the standard deviation values, and the minimum and maximum scores for each of the variables, during the pre-and post-course surveys. The positive values of the absolute mean difference between the pre- and post-survey results show sustainability and FEP knowledge improvement among the participants. Additionally, Table 2 highlights the p-values for each variable. The results indicate that the collaborative framework was significantly effective in (1) helping the students to understand the importance of FEP and Sustainable Infrastructure rating systems; (2) facilitating the students' understanding of the importance of team alignment between project stakeholders; (3) allowing the students to be familiar with project scope definition; (4) increasing students' knowledge of stakeholders' early involvement in the project; (5) helping students to differentiate between Front-End Planning (FEP) and traditional Planning/Scheduling; and (6) allowing students to learn about infrastructure projects and their importance to the built environment. Thus, the results highlight that the PBL method significantly increased the participants'

sustainability knowledge and skills and provided them exposure to how real-life sustainability projects are managed.

Table 1. Descriptive statistics of Wilcoxon signed-rank test (n=35)

V.N.	Variables	Absolute Mean Difference	Std. Deviation	Minimum	Maximum
1 - Pre	Understanding the importance of FEP and Sustainable Infrastructure rating systems (i.e., the Envision rating system)	0.52	1.065	1	5
1 - Post			0.981	2	5
2 - Pre	Understanding the importance of team alignment between project stakeholders, including designers, contractors, consultants, and the community	0.37	1.083	1	5
2 - Post			0.917	2	5
3 - Pre	Defining the scope of a project prior to the design phase	0.43	1.023	1	5
3 - Post			0.973	2	5
4 - Pre	Effective team alignment during FEP (i.e., involvement of all project stakeholders very early in the project)	0.54	1.132	1	5
4 - Post			0.906	2	5
5 - Pre	Differentiating Front-End Planning (FEP) from traditional Planning/Scheduling	0.66	1.262	1	5
5 - Post			1.008	2	5
6 - Pre	Understanding the importance of infrastructure projects to the built environment	0.42	1.095	1	5
6 - Post			1.011	2	5

Table 2. Wilcoxon signed-rank test statistics results

VN	1	2	3	4	5	6
Z	-2.99	-2.144	-2.431	-3.065	-3.62	-2.839
Asymp. Sig. (2-tailed)	0.003	0.032	0.015	0.002	0	0.005
p - value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Assessing Students' Professional Skills Development

The post-survey asked the students how the implemented framework helped them improve their soft skills including (1) Leadership; (2) Communication; (3) Critical thinking; (4) Teamwork; (5) Project Management; and (6) Knowledge Retention. The students were presented with 12 statements associated with these six skills and were allowed to self-assess themselves based on a five-point Likert Scale (1 being Strongly disagreed and 5 being Strongly agreed). Figure 4

presents the Likert Scale responses through boxplots. The median value based on students' self-reported responses indicates that the activity could successfully improve most the students' professional skills. The outliers in the boxplot indicate that few students did not feel that the activity helped them to improve their soft skills. These students might require additional learning pedagogies that can successfully foster their professional growth. Therefore, such activities should be integrated into the curricula more often to nurture students' soft skills and provide them an edge in their careers.

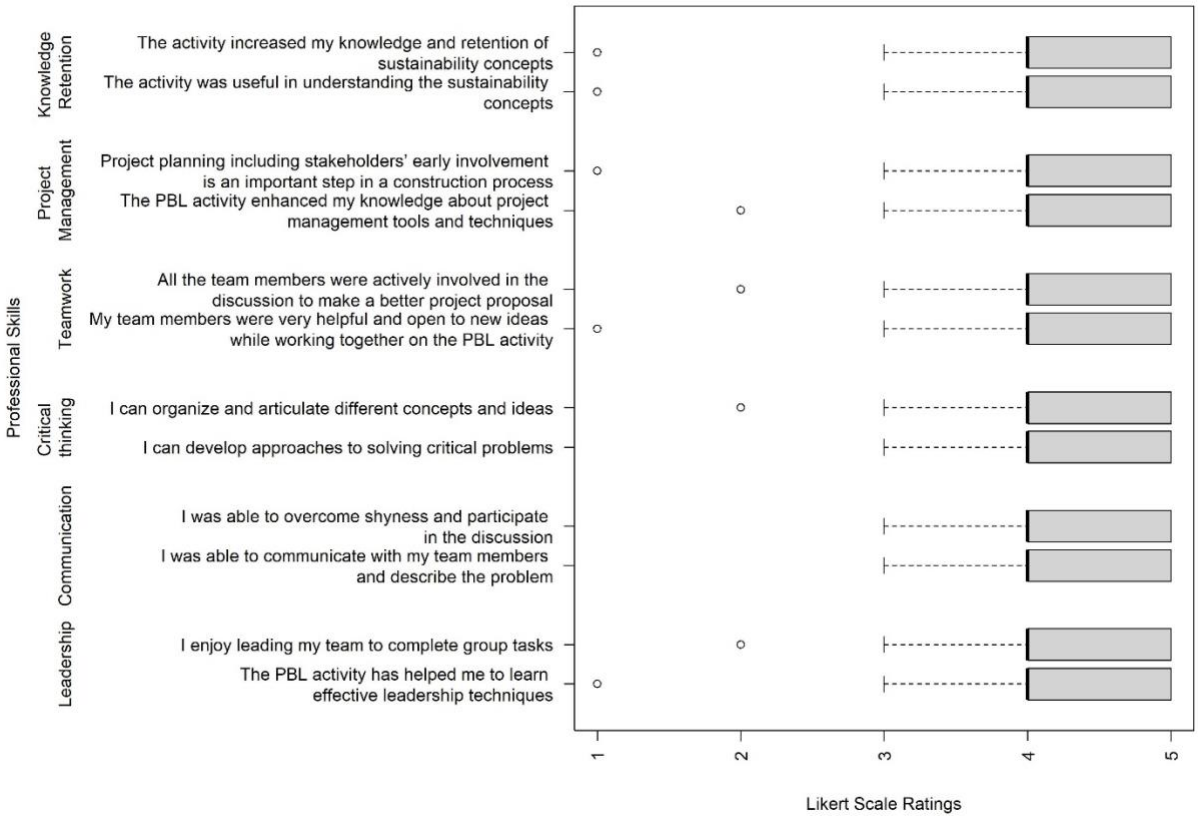

Figure 4. Boxplots showing students' professional skill development through the PBL activity

Moreover, the students were presented with open-ended questions. Figure 5 (a) demonstrates the likes and dislikes of the students about the PBL activity. Most of the students preferred the teamwork and interactiveness of the activity whereas the time constraint of the activity was not appreciated. Figure 5(b) presents the list of the impacts of the in-class PBL activity according to the participants. The results show that the activity helped them understand how projects are managed in the real construction world. The students also highlighted that the framework increased their knowledge of the practical application of FEP and sustainable infrastructures. Moreover, the students shared that the activity enhanced their awareness of environmental impacts and how sustainable development can mitigate those impacts. Other impacts involved improving problem-solving skills, refining ideas through discussing with peers, increased familiarity with FEP as well as quick decision-making during time constraint situations. Only 2 out of 35 students thought that the activity did not make any change to their knowledge or skills.

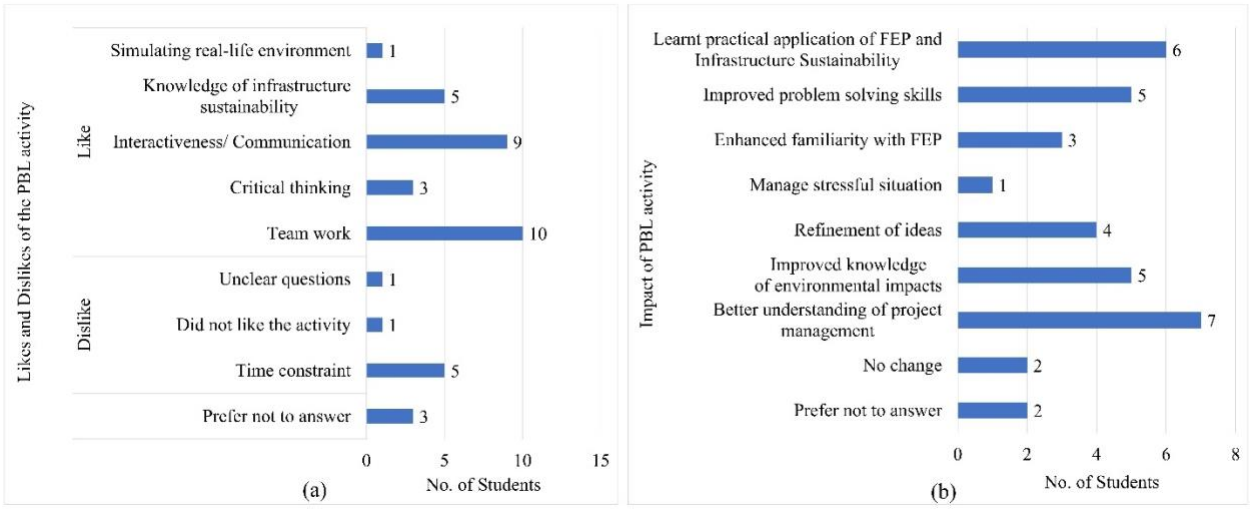

Figure 5. (a) Students' likes and dislikes about the PBL activity; and (b) Impacts of the PBL activity

Discussion

Sustainable projects pose additional challenges to the project team members due to the higher complexity associated with these projects. Integrating FEP into these projects can facilitate successful project delivery by aiding in project design, construction, and operational phases. Such integration allows for increased clarity in the project scope as well as enhances involvement for various project stakeholders. Utilizing pre-project planning tools can help in detailed scope definitions of a project which can aid a smooth transition from planning to design and construction phase of a project. Such detailed scope definition minimizes project-related uncertainty which leads to reducing various risks associated with sustainable infrastructure projects. Integrating pre-project planning can facilitate the project stakeholders to determine adequate cost and schedule baselines thus aiding in the procurement process. Utilizing FEP tools in sustainable infrastructure projects can create a strong foundation for project control resulting in improved project cost, schedule, and quality as well as reduced change orders. Moreover, different certification levels of the existing sustainability rating system can contribute to projects' quality management and facilitate quality assurance. Thus, teaching sustainability and pre-project planning concepts to the CM students including minority students can nurture their ability to develop a good project working plan that can avoid substantial project change orders and ensure successful project delivery. Integrating sustainability and relevant concepts in construction education can foster sustainability knowledge and skills among future professionals which can influence them to use effective pre-project planning tools and techniques. Educating students about the FEP techniques and sustainability practices through construction education can cultivate the expertise and competencies that are required to better manage the real-world challenges pertaining to sustainable construction.

Moreover, to become competent engineers and construction managers, minority students must invest in developing their professional skills. Thus the results of this study contribute to

classroom management, curriculum, and the recruitment and retention of under-represented groups in engineering. For instance, an emphasis on active learning through the early and pervasive use of design in the engineering curriculum can have improved classroom engagement of minority students. This pedagogical strategy, as shown in this study, promotes effective communication skills, leadership skills, and group participation skills. Structuring classroom activities based on active learning may require specialized abilities and knowledge requiring training and experiences for the faculty members. The educational institutions must assess the faculty reward criteria, standards, and policies to provide adequate incentives to encourage faculty to pursue the instructional goals of developing improved and pragmatic curricula. Additionally, the PBL technique can be a potential candidate for sustainability and cognitive skill teaching efforts, particularly within construction education for minority students. The CM students' self-judgment highlighting the positive impacts of the PBL activity reinforces the same conclusion in the study. The findings of this study provide empirical support to the effectiveness of active learning methods such as Problem Based Learning to develop minority students' sustainability and professional skills. While adoption of these learner-active approaches may require changes in current course designs, the positive outcomes of this study suggest that efforts to make those changes are likely to be educationally worthwhile.

Limitation

The authors acknowledge some limitations of this study. The self-reported skill levels may not represent the actual skill levels of the students and may be subject to over or underestimation. Another limitation may be that the effectiveness of the proposed collaborative approach to improve sustainability knowledge and professional skill may vary between institutions and settings.

Conclusion

This study evaluated the effectiveness of Problem Based Learning (PBL) as a part of the teaching effort to impart sustainable infrastructure and relevant knowledge while nurturing professional skills among construction management students including minorities. Such effort can substantially contribute to cultivating diversity among sustainable professionals as well as nurture their nontechnical yet essential skills. This study implemented an intervention framework involving a PBL activity in a cross-listed Sustainable Approach to Construction course which introduced the students to sustainable infrastructure and Front-End Planning (FEP) techniques and how they complement each other to build sustainable infrastructure systems effectively. The comparison of pre- and post-survey indicates that the PBL activity significantly improved the students' knowledge related to infrastructure sustainability and Front-End Planning (FEP). Moreover, the students' self-assessments highlighted that the framework effectively improved most the participating students' professional skills including leadership, communication, critical thinking ability, working in teams, and project management aligning with ABET outcome. The findings of this research indicate that Problem Based Learning (PBL) framework can play a critical role in teaching sustainability knowledge as well as improve CM students including

minorities' non-technical professional skills which engineering graduates should be equipped with while embarking upon a professional career in the industry.

References

[1] J. Elkington, "Accounting for the Triple Bottom Line," *Meas. Bus. Excell.*, vol. 2, no. 3, pp. 18–22, 1998, doi: 10.1108/eb025539.

[2] R. Valdes-Vasquez and L. Klotz, "Incorporating the social dimension of sustainability into civil engineering education," *J. Prof. Issues Eng. Educ. Pract.*, vol. 137, no. 4, pp. 189–197, 2011, doi: 10.1061/(ASCE)EI.1943-5541.0000066.

[3] P. Pradhananga and M. Elzomor, "Environmental Implications of Quarry Rock Dust: A Sustainable Alternative Material to Sand in Concrete," 2020, vol. 2020, pp. 809–818.

[4] ISI, "Envision Rating System for Sustainable Infrastructure." Washington, DC, 2015.

[5] R. Rahat, V. Ferrer, P. Pradhananga, and M. ElZomor, "Assessing pedagogical paradigm for coupling FEP and sustainability practices." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2021, doi: https://doi.org/10.3886/E152102V1.

[6] K. Vandebergh, N. Augustus, and C. Peterson, "Ridgewood view park reservoir and pump station: A case study on envision verification," *J. Am. Water Works Assoc.*, vol. 108, no. 6, pp. 51–56, 2016, doi: 10.5942/jawwa.2016.108.0099.

[7] E. Bingham and G. E. Gibson, "Infrastructure Project Scope Definition Using Project Definition Rating Index," *J. Manag. Eng.*, vol. 33, no. 2, p. 04016037, 2017, doi: 10.1061/(asce)me.1943-5479.0000483.

[8] J. Sindhu, K. Choi, S. Lavy, Z. K. Rybkowski, B. F. Bigelow, and W. Li, "Effects of Front-End Planning under Fast-Tracked Project Delivery Systems for Industrial Projects," *Int. J. Constr. Educ. Res.*, vol. 14, no. 3, pp. 163–178, 2017, doi: 10.1080/15578771.2017.1280100.

[9] M. Elzomor, V. Ferrer, P. Pradhananga, and R. Rahat, "Assessing the Pedagogical Needs to Couple Front-end Planning Tools with Sustainable Infrastructure Projects," 2021, doi: 10.18260/1-2--36721.

[10] ASCE, "The Vision for Civil Engineering in 2025," *Am. Soc. Civ. Eng.*, vol. 18, no. 4, pp. 651–660, 2007.

[11] N. D. McWhirter and T. Shealy, "Teaching decision-making for sustainable infrastructure: a wind energy case study module," *Int. J. Sustain. High. Educ.*, vol. 19, no. 5, pp. 893–911, 2018, doi: 10.1108/IJSHE-10-2017-0183.

[12] N. McWhirter and T. Shealy, "Case-based flipped classroom approach to teach sustainable infrastructure and decision-making," *Int. J. Constr. Educ. Res.*, vol. 16, no. 1, pp. 3–23, 2020, doi: 10.1080/15578771.2018.1487892.

[13] M. Elzomor and K. Parrish, "Positioning students to understand urban sustainability

strategies through vertical integration: Years one through four," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2017-June, 2017, doi: 10.18260/p.25915.

[14] M. A. Reyes, M. R. Anderson-Rowland, and M. A. McCartney, "Learning from our minority engineering students: Improving retention," *ASEE Annu. Conf. Proc.*, pp. 4007–4016, 2000, doi: 10.18260/1-2--8536.

[15] C. A. Berry and D. Walter, "ROSE-BUD (rose building undergraduate diversity) MAPS (mentoring and professional skills)," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2013, doi: 10.18260/1-2--22436.

[16] Z. Wood, E. L. Costello, A. Keen, and C. Eckhardt, "A cross-disciplinary minor to engage student's creativity and engineering skills," 2019.

[17] ABET, "CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS (2022-2023)." pp. 1–51, 2021.

[18] P. Pradhananga, M. Elzomor, G. Santi, and L. Zhang, "Fostering virtual reality environments to advance construction and engineering students' interpersonal skills," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2020-June, 2020, doi: 10.18260/1-2--34686.

[19] P. Pradhananga, M. Elzomor, G. Santi, and A. M. Sadri, "Integrative pedagogical framework to support construction students' professional skills and engagement," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2020-June, 2020, doi: 10.18260/1-2--34856.

[20] H. Garcia-Reyes and C. De La Garza Garza, "A problem based learning framework to assess and develop soft skills in a linear programming course," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2015, vol. 122nd ASEE, no. 122nd ASEE Annual Conference and Exposition: Making Value for Society, doi: 10.18260/p.23427.

[21] R. D. Webster, "Industry supplied CAD curriculum and team project-based learning: Case study on developing design, problem-solving, communication, and group skills," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2017, vol. 2017-June, doi: 10.18260/1-2--28523.

[22] N. Barclay, "Problem-based learning: Perceptions and impact on student learning in a sustainable infrastructure course," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2020, vol. 2020-June, doi: 10.18260/1-2--35086.

[23] B. B. Elmore, "Integrating problem-based and project-based learning in large enrollment freshman engineering courses," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2017, vol. 2017-June, doi: 10.18260/1-2--28557.

[24] P. M. Yanik, C. W. Ferguson, S. Kaul, and Y. Yan, "A pilot program in opem-ended problem solving and project management," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2017, vol. 2017-June, doi: 10.18260/1-2--27494.

[25] J. Russell, O. Pierrakos, M. France, R. Kander, R. Anderson, and H. Watson, "Incorporating problem based learning (PBL) in a freshman engineering course: Implementing methods for classifying and assessing PBL projects," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2010.

[26] M. Elzomor, C. Mann, K. Doten-Snitker, K. Parrish, and M. Chester, “Leveraging Vertically Integrated Courses and Problem-Based Learning to Improve Students’ Performance and Skills,” *J. Prof. Issues Eng. Educ. Pract.*, vol. 144, no. 4, 2018, doi: 10.1061/(ASCE)EI.1943-5541.0000379.

[27] E. Forcael, V. González, F. Orozco, A. Opazo, Á. Suazo, and P. Aránguiz, “Application of problem-based learning to teaching the critical path method,” *J. Prof. Issues Eng. Educ. Pract.*, vol. 141, no. 3, pp. 1–11, 2015, doi: 10.1061/(ASCE)EI.1943-5541.0000236.

[28] A. Prieto, D. Días, M. Hernández, and E. Lacasa, “Methodological variants of PBL: The 4 × 4 PBL. The problem-based learning in higher education.” J. García, ed., Univ. of Murcia, Murcia, Spain, pp. 55–74, 2008.

[29] G. E. Gibson and P. Dumont, “Project definition rating index.,” *Implement. Resour.*, vol. 113, pp. 113–11, 1996.

[30] G. E. Gibson, J. H. Kaczmarowski, and H. E. Lore, “Preproject-Planning Process for Capital Facilities,” *J. Constr. Eng. Manag.*, vol. 121, no. 3, pp. 312–318, 1995, doi: 10.1061/(asce)0733-9364(1995)121:3(312).

[31] CII, “Front End Planning: Break the Rules, Pay the Price. Research Summary 213-1.” Construction Industry Institute, Austin, TX, 2006.

[32] S. Hansen, E. Too, and T. Le, “Retrospective look on front-end planning in the construction industry: A literature review of 30 years of research,” *Int. J. Constr. Supply Chain Manag.*, vol. 8, no. 1, pp. 19–42, 2018, doi: 10.14424/ijcscm801018-19-42.

[33] N. McWhirter and T. Shealy, “Bridging engineering and psychology: Using an envision gold certified project to teach decision making for sustainability,” *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2017-June, 2017, doi: 10.18260/1-2--27978.

[34] L. Brunell, “A real-world approach to introducing sustainability in civil engineering capstone design,” *ASEE Annu. Conf. Expo. Conf. Proc.*, 2019.

[35] C. Boyle *et al.*, “Delivering sustainable infrastructure that supports the urban built environment,” *Environ. Sci. Technol.*, vol. 44, no. 13, pp. 4836–4840, 2010, doi: 10.1021/es903749d.

[36] G. Weerasinghe, K. Soundararajan, and J. Ruwanpura, “LEED – PDRI Framework for Pre-Project Planning,” *J. Green Build.*, vol. 2, no. 3, pp. 123–143, 2007.

[37] L. B. Robichaud and V. S. Anantatmula, “Greening Project Management Practices for Sustainable Construction,” *J. Manag. Eng.*, vol. 27, no. 1, pp. 48–57, 2011, doi: 10.1061/(asce)me.1943-5479.0000030.

[38] A. Scolobig and J. Lilliestam, “Comparing approaches for the integration of stakeholder perspectives in environmental decision making,” *Resources*, vol. 5, no. 4, 2016, doi: 10.3390/resources5040037.

[39] A. B. Braun, A. W. da S. Trentin, C. Visentin, and A. Thomé, “Sustainable remediation through the risk management perspective and stakeholder involvement: A systematic and bibliometric view of the literature,” *Environ. Pollut.*, vol. 255, 2019, doi:

10.1016/j.envpol.2019.113221.

[40] P. Pradhananga, M. ElZomor, and G. Santi Kasabdji, “Advancing Minority STEM Students’ Communication and Presentation Skills through Cocurricular Training Activities,” *J. Civ. Eng. Educ.*, vol. 148, no. 2, pp. 1–16, 2022, doi: 10.1061/(asce)ei.2643-9115.0000060.

[41] J. C. Nunnally, *Psychometric theory*. New York : McGraw-Hill, 1978.

[42] O. K. Robert, A. Dansoh, and J. K. Ofori-Kuragu, “Reasons for adopting Public-Private Partnership (PPP) for construction projects in Ghana,” *Int. J. Constr. Manag.*, vol. 14, no. 4, pp. 227–238, 2014, doi: 10.1080/15623599.2014.967925.