Implementing Active Learning Strategies in Teaching Building Systems, Safety, and Services: A Case Study in Civil Engineering Education

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***Abstract*—Active learning has proven to be a successful strategy to enhance engagement and applied competence amongst learners of engineering. Traditional lecture-based courses included in civil engineering education tend to lack the linkage between theoretical and field-based applications. This paper provides a case study of the implementation of project-based and experiential learning environments and the course Building Systems, Safety, and Services (BSSS) in order to increase student engagement and applied learning. Activities that are incorporated in the methodology include plumbing and electrical layout drafting, poster and PowerPoint presentation, and fire-safety demonstration that is facilitated by instructors and professional expert sessions. The descriptive statistics and qualitative reflections were used to analyze the student feedback of 28 participants. The findings have shown that there is a great deal of improvement in visualization, design, and safety awareness with more than 90 percent of students stating that they have increased confidence and practical learning outcomes. The results are also consistent with other literature that identifies the usefulness of interactive pedagogies in engineering education. The study concludes that active-learning frameworks not only fill the gap between theory and practice but also resonate with Sustainable Development Goals (SDG 4 and SDG 11), which make civil engineers employable and prepare them to meet industry challenges.**

***Keywords*—Active Learning; Project-Based Learning; Building Systems Safety and Services; SDG.**

***ICTIEE* Track*:* Innovative Pedagogies and Active Learning**

ICTIEE Sub-Track: Collaborative and Experiential Learning Models

I. INTRODUCTION

Building systems, safety, and services (BSSS) courses play a critical role in the education of civil engineers since they equip students with the primary practical concepts of the different services involved in building, such as plumbing, electricity, air conditioning, acoustic, fireproofing systems, and building safety concepts in construction. These courses play a vital role in ensuring that built environments are sustainable and safe, complex issues that lecture-based coursework cannot always attract students to or teach them practical skills. The industry requirements and the National Building Code (NBC) of India require engineers who are trained in maintenance, repair, and safety management. However, challenges such as abstract concepts and a lack of practical exposure have negative impacts on the learning process.

The paper presents the pedagogical redesign of the BSSS course, where active learning methodologies have been applied to enhance student learning and skills. Activities consisted of electric and plumbing layout drawings; fire safety demonstrations; poster presentations; and collaborative learning of advanced technology in building services and construction, based on the experiences of the students in the prior semester. The strategy is to develop problem-solving, teamwork, and implementation skills according to the course requirements, such as a broad understanding of maintenance subject matter, acquired skills of building services infrastructure, safety requirements, and practical building-up engagements across various construction phases.

The study deals with the impact by presenting the qualitative consideration of the research of methodology, which applies to the explanation of effective learning in the field of civil engineering. It addresses literature gaps with integrated services and safety with parallel connections to SDGs regarding sustainable education and urban development.

The increasing focus on competence-based engineering education underscores the necessity of new pedagogies that can be used to apply theoretical knowledge into practice. The usual lecture mode delivery in subjects like Building Systems, Safety, and Services (BSSS) tends to inhibit student participation and real-world knowledge. To overcome this difficulty, the current study will examine how active-learning, planned strategies may improve student engagement, skill acquisition, and professional preparedness.

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II. LITERATURE REVIEW

Transformation of engineering education into active learning has also made engineering education redefine, where interactive student-centered practices have replaced passive lectures (Jadhav & Deshpande, 2025). The outcomes of the real-life project assessment were used in the project-based learning proposal in civil engineering to show improved critical thinking and collaboration (Meti et al., 2024). Similarly, the geometrical road patterns contributed to a better understanding of the STEM-based practices and performance (Ragadhita et al., 2025).

Project-based learning (PBL) has been especially effective in the field of civil and construction engineering in bridging the gap between theoretical knowledge and professional practice. As presented in (Meti et al., 2024) real-life project evaluation contributed to the enhanced awareness of measurement systems and teamwork skills. In the same manner, (Kalyani et al., 2024) adopted PBL in a course on Digital Signal Processing with similar results, as students had enhanced problem-solving and self-directed learning. (Jadhav & Deshpande, 2025) used active learning in MEP and quantity surveying, demonstrating that collaboration with simulations enhanced motivation and understanding levels. These studies together prove that project-based pedagogies can stimulate creativity, responsibility, and competence in problem-solving in engineering students.

The importance of the technology-enhanced and immersive learning environments is also supported by the recent evidence, showing that the experience based on virtual reality demonstrates that the engagement with cognitive processes and the understanding of concepts is significantly reinforced by the experience based on the use of interactive digital tools in the engineering curriculum (Álvarez-Marín & Velazquez-Iturbide, 2022; Bhogayata et al., 2025). Flipped classes transform the concept of quality by incorporating technology into a deeper involvement (Katona & Gyonyoru, 2025; Zhang et al., 2019). Active learning competencies of teachers are focused on facilitation and assessment planning (Ebekozien et al., 2023). Outside of classroom applications, simulation-based and experiential pedagogies have demonstrated a tremendous potential in the field of construction safety and building-services education. It was proven that Building Information Modelling (BIM) integrated learning improves visualization, coordination, and multidisciplinary collaboration (Ahn et al., 2016; Otieno et al., 2025). Similarly, (Babu et al., 2024; Tohe et al., 2025) established that micro lesson preparation, case studies, and laboratory-based teaching could aid in meeting Sustainable Development Goals (SDGs), which involve encouraging application-oriented and reflective learning.

Regardless of these developments, not many studies have tried to combine various building services fields, plumbing, electrical, HVAC, and fire-safety systems into a single pedagogical framework. In the current literature, these elements are mostly considered separately, and this restricts the development of the overall view of the network of systems that assures functionality and safety of buildings. To fill this gap, the current research paper will add a detailed active-learning case study to the Building Systems, Safety and Services (BSSS) course in civil-engineering education. This work is a combination of project-based drawing, fire-safety demonstration, poster, and presentation activities, as well as reflective analysis, which creates a harmonious method that connects theoretical learning with the practical field. It also complies with SDG 4 (Quality and SDG 11 (Sustainable Cities and Communities) as it helps increase employability, sustainability awareness, and professional readiness of the future civil engineer (Novaes, 2025).

III. METHODOLOGY

A. *Research Framework*

This present study follows the qualitative case-study approach based on the principles of the action-research research, which tends to assess the effectiveness of active learning strategies in the Building Systems, Safety and Services (BSSS) course.

The methodology is based on the research question framework that how project-based and experiential learning activities can be combined to make students more engaged in civil-engineering learning. To study this framework following aims are predefined.

a) Design and implement active-learning activities aligned with course outcomes and industry standards.
b) Assess the impact of these activities on student engagement and applied competence.
c) Analyze the feedback and reflections to refine the pedagogical framework for broader application.

The methods used to collect data included a course-end survey (n = 28), peer evaluation, and reflections of the instructors. The qualitative thematic analysis was used alongside descriptive statistics in terms of mean and percentage agreement to interpret the perceptions of the students and determine the learning outcomes. This methodology assures methodological triangulation and increases the validity of results.

B. *Course Design and Objectives*

The BSSS course is an elective course for civil engineering undergraduates and has prerequisites in Building Construction and Planning. Knowledge of plumbing/electrical maintenance, practical system design, safety regulations, and application in different phases of construction is included among the objectives.

The syllabus is divided into four units, which are Introduction, Building Systems and Services, including plumbing, electrical, lighting, vertical transportation, air conditioning, Miscellaneous Services such as solar heating, acoustics, fire protection, rainwater harvesting, and Building Safety, such as site requirements, substructure/superstructure safety. The primary aim of the course is that students will acquire information on various building services and safety requirements during the construction period, and they are expected to practice them on-site.

C. Teaching-Learning Methodology

The teaching philosophy is a combination of lectures and active learning elements to facilitate interaction and skill development. Lectures use multimedia presentations and whiteboards to introduce concepts, while active elements encourage application and collaboration. Key strategies are detailed below.

D. Plumbing and Electrical Layout Drawings

Students engage in drawing basic plumbing and electrical plans for residential or commercial buildings using AutoCAD. This hands-on activity begins with instructor-guided tutorials on reading NBC standards and symbols. Individual students create 2D/3D layouts, incorporating water storage, distribution, drainage, wiring, switches, and safety devices.

Initially, the review of the prerequisites of plumbing and electric lines is explained according to an actual field scenario. In class step by step-by-step drafting with peer feedback sessions was arranged according to the building layout and requirements. Students present layouts to peers and propose alternatives which should be economic and feasible options on site, and which kind of challenges may be possible in each option. Finally, based on the peer feedback review and site constraints, the modified layout was prepared for the submission and evaluation

This method gives visualization, technical drawing skills, and critical evaluation, along with an understanding of on-site issues related to plumbing and electricity lines. The sample drawings of electric and plumbing layouts prepared by students are shown in Figure 1.

E. Poster and PowerPoint Presentation

Students prepare PowerPoint presentations and posters on topics like innovations in building services (e.g., smart plumbing, fire-resistant materials) or safety in construction phases. A key focus is on advancements in the construction and safety industries. The choice of these topics is to connect the theoretical knowledge with the new trends in the industry so that students can investigate how technologies such as robotics in the construction industry or advanced fire suppression systems could improve efficiency and safety.

There were assigned topics such as:

1. Smart Building Technologies (e.g., IoT, AI, and automation for energy management and security).
2. Sustainable Plumbing Solutions (e.g., rainwater harvesting, greywater recycling, and biodegradable materials).
3. Electrical Safety Innovations in Construction (e.g., smart circuit breakers and AI-driven fault detection).
4. Designing Accessible Buildings for All (e.g., ramps, elevators, and tactile paving for disabilities).
5. Innovative Vertical Transportation Systems (e.g., high-rise energy-efficient elevators).
6. The Future of Building Acoustics (e.g., application of soundproofing materials for residential or commercial buildings).

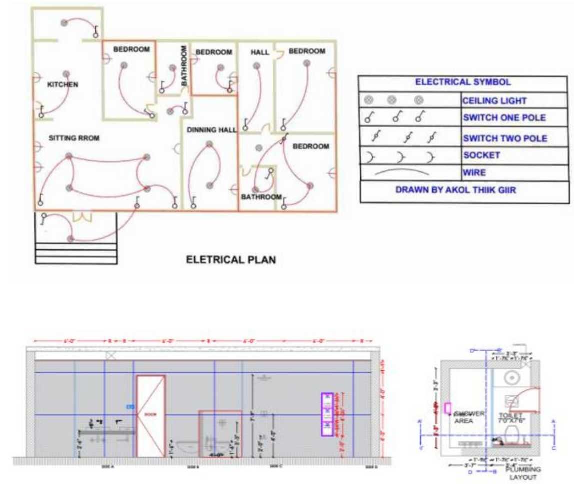

Fig. 1. Electric and Plumbing Layouts in Building

7. Integrating Solar Energy in Building Systems (e.g., solar panels and passive solar design).
8. Advanced Ventilation Systems for Indoor Air Quality (e.g., smart filtration and real-time monitoring).
9. Fire Safety Strategies in Modern High-Rise Buildings (e.g., automated suppression systems).
10. Advanced Water Management Systems (e.g., smart meters and leak detection).
11. Lighting Design for Energy Efficiency (e.g., LED and daylight harvesting).
12. Digital Twin Technology in Building Services (e.g., virtual replicas for predictive maintenance).
13. Emerging Trends in HVAC Systems (e.g., geothermal pumps and smart thermostats).
14. Zero-Energy and Net-Zero Building Design (e.g., energy-efficient materials).
15. Advanced Building Services Management (e.g., BMS with IoT).
16. Virtual Reality (VR) and Augmented Reality (AR) in Construction (e.g., safety training).
17. Circular Economy in Construction (e.g., material reuse and waste minimization).
18. Building Security System (e.g., access control and drone surveillance).
19. Innovations in Construction Safety Management (e.g., wearables and drones).
20. Upcoming Trends in Building Construction Technology (e.g., BIM advancements and 3D printing).
21. Advanced Construction Robotics (e.g., autonomous robots and drones)

For presentation evaluation, at the beginning of the semester, instructors form the groups and select topics aligned with units (e.g., escalator design for physically abled access or advancements in zero-carbon building services).

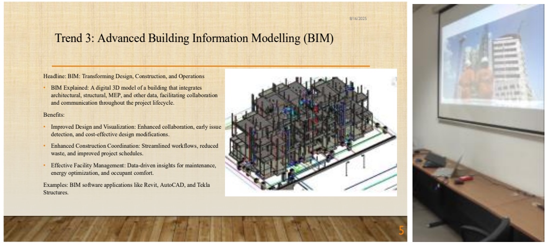

Fig. 2. Powerpoint presentation by the students

Fig. 3. Poster presentation by the students

Instructors provide a curated list of resources to guide research on advancements. Also, instructors have guided library sessions and online resources for content gathering, emphasizing critical analysis of advancements (e.g., comparing traditional vs. AI-based safety protocols). Instructors facilitate flipped classroom elements, where students pre-read articles on industry innovations and discuss in class before drafting slides. Teaching methods include scaffolded guidance: initial brainstorming sessions to outline key advancements, peer review workshops for refining content, and instructor feedback on integrating real-world examples like NBC-compliant innovative fire systems. Each presentation will take 10-15 minutes with questions and answers, and will focus on good ways of representation, presentation skills, and communication with the audience. Several of these learning techniques use a debate style wherein the students justify how a given improvement is going to solve the industry problems, encouraging further insight into the topic through the discussion and presentation of arguments and evidence. The sample PowerPoint presentation offered by the students is shown in Figure 2.

Concerning the poster, the learners have designed it with the aid of different applications, such as Canva or Adobe, to make it visually attractive and give importance to the essential visuals. Students make drafts during the collaborative sessions, where they use design-thinking techniques to mark improvements, i.e., flowcharts to describe the transformation of manual safety checks to automated ones. Gallery walks are set up, and peers are critiquing and offering suggestions on how to improve. Teaching-learning techniques involve inquiry-based learning, which involves the students' asking questions on posters (e.g., How does BIM promote plumbing efficiency?), and group discussions, which promote the promotion of self-directed learning about industry trends. Post-presentation reflection questions encourage the student to relate progress to the goals of the course, supporting experiential learning. Figure 3 shows the sample poster presentation.

Such activities will encourage research, communication, and creative synthesis, where students present and prepare actively to simulate professional industry seminars and presentation and graphical skills.

F. Hands-On Practice and Demonstrations

The practical experience and demonstration aspect of this course is the most important element, as it is intended to immerse students into real-world safety and operation conditions to further develop their practical expertise and knowledge of building systems.

This section is more about fire safety demonstrations, replicating the installation and operation of key safety elements, including fire lifts, exterior stairs, and fire suppressors, and follows the standards as developed by the (*National Building Code of India 2016*, n.d.)

It starts with an extensive theoretical orientation, during which the professionals of the industrial field provide lectures on the reasons for fires, the characteristics of fire-resistant materials, and the legal standards of fire safety installations. This theoretical background sets the stage for practical application.

Subsequently, students participate in demonstration sessions equipped with tools such as fire extinguishers, fire safety equipment, and alarm systems, allowing them to engage directly with the equipment. Such sessions are also interactive, and they involve using role-plays of students simulating emergency procedures, including evacuating a building or responding to a fire breakout, to nurture pressure decision-making. Moreover, group activities will help the students develop hypothetical plans of fire protection of the building based on group approaches, including such issues as sprinkler systems and emergency exits, and provide them with debriefing sessions to consider the loss of attempts and take into account to understand the practical result of their choice given in detail.

These activities are supplemented by expert lectures, with industry professionals who provide an opportunity to discuss fundamental aspects, including case studies, latest advances in construction safety. Figure 4 shows a glimpse of a fire safety demonstration by the industry expert.

Expert lectures from industry professionals involve two-way discussions on topics like construction safety. For the hands-on training session on safety.

Fig. 4. Illustrative overview of standard fire-safety equipment used during demonstration sessions

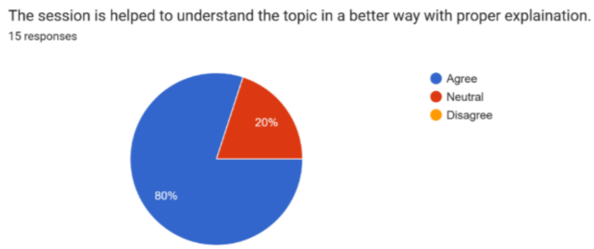

Fig. 5. Feedback of Expert Session

As Figure 5 shows, when asked about feedback, 15 students reported that 80% of them thought that the proper explanation made them better understand the topic, and that 20 percent were neutral, with no one disagreeing on the fact that expert-led, interactive training is valuable in getting theoretical knowledge and acting as a bridge between a theoretical explanation and practical skills.

This affirmative reaction highlights the usefulness of professional knowledge in complex safety issues in terms of interactive conversations and practical cases.

G. Overall Integration and Facilitation

The progression of the teaching exercises was well coordinated, and it started with the basic practice of technical drawings and then proceeded towards poster presentations and demonstration lessons. Faculty members took the role of facilitators, providing a personalized direction and formative feedback with the help of systematic one-on-one reviews. Students were encouraged to engage in self-directed learning and accountability by attending classes consistently and participating actively. Reflective practice was interwoven with post-activity journals, where students reflected on the challenges, experiences, and lessons, and provided notes on the important learning experience.

To evaluate, detailed evaluation rubrics were created and shared with students on a case-by-case basis to bring about transparency and uniformity in evaluation. The rubrics covered a variety of dimensions, which include accuracy and completeness of layout drawings, content quality and visual presentation in presentations and posters, and the degree of participation and engagement in expert-led or hands-on training. This assessment model allowed objective views and strengthened the purposeful learning outcomes of the course.

The proposed active-learning model was not only validated through the quantitative approach but also through the use of a qualitative approach to ensure reliability and validity. The quantitative part was a student-feedback survey ($n = 28$) in the form of structured questions in 1 to 5 Likert-scale questions created to measure engagement, skill development, collaboration, and general satisfaction. The descriptive statistical methods were used to calculate mean values, standard deviations, and percentage agreement of each indicator. To supplement this, qualitative validation was also conducted based on thematic analysis of open-ended student responses and instructor commentaries, resulting in the recurrence of concepts of improvement, challenge, and adaptive learning. These two

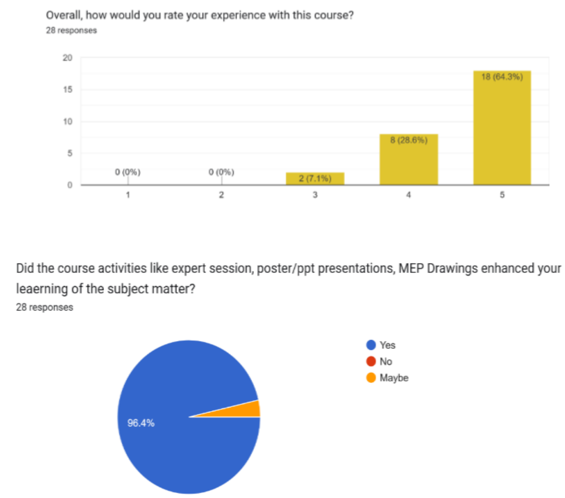

Fig. 6. Sample Course End Survey

analytical strands converged and resulted in internal consistency, which proved that the presentation-based and project-based learning framework was an effective tool to enhance cognitive knowledge, professional readiness, and reflective learning in students.

IV. Student Feedback and Analysis

At the end of the semester, survey data were gathered through anonymous surveys of students. Out of that, 28 have answered in the course-end survey. The survey involved a perceived effect of active learning activities, skill development, instructor feedback, and overall course experience as demonstrated in Figure 6.

The analysis of quantitative data collected through the course-end feedback survey was conducted with the help of descriptive statistics to assess consistency and central tendency of the answers. The four parameters that were to be measured included Engagement, Practical Skill Improvement, Conceptual Understanding, and Teamwork, measured on a five-point Likert scale (1 = strongly disagree to 5 strongly agree). Table I presents the results of the summary that indicate high mean scores (between 4.4 and 4.7) but low standard deviations (between 0.32 and 0.41), which is a good indication that there is a high degree of agreement among participants.

Table I
Descriptive Summary of Student Feedback

Parameter	Mean	Standard Deviation	% Agreement
Engagement & Interest	4.7	0.32	96.4 %
Practical Skill Improvement	4.6	0.34	92.9 %
Conceptual Understanding	4.5	0.38	89.3 %
Teamwork & Collaboration	4.4	0.41	85.7 %

The topics that were revealed as student feedback, increased engagement, practical confidence, and teamwork, are the same ones as the evidence given in the previous studies on active learning. It was shown that interactive and project-based approaches show visible growth in retention and examination results (Freeman et al., 2014; Prince, 2004). Similarly, (Jadhav & Deshpande, 2025; Kalyani et al., 2024) observed increased student motivation and deeper understanding when problem-based approaches were introduced in engineering courses. The strong rates of agreement found in the current research (more than 90 % of students reporting on the enhanced practical skills and knowledge), thus, support a wider body of literature, and confirm that structured experiential learning is also an effective measure to fill the gap between the theoretical teaching and the professional competency.

The outcome of the quantitative validation revealed that students demonstrated high levels of agreement with the results, where the average scores were more than 4.5 on all the parameters of engagement, understanding, and collaboration. Thematic feedback analysis showed that the same descriptors were repeated: interactive, realistic, and industry-oriented, which confirms that the learning model was more conceptually clear and practically relevant.

Adiditonal statistics in the feedback cover particular advantages 96.4% of students said they could better develop practical skills (e.g. drawing and presentation skills) and new perspectives, 92.9% said that they could better remember safety protocols through demonstrations and timely feedback, and 85% (calculated based on qualitative responses) felt better prepared to work in an industry as a result of exposure to developments in presentations/posters. The focus on interactivity and the real world, as it was stressed in qualitative remarks, was marked as the distinguishing features, and statements such as the following were made: The presentations of smart technologies made abstract ideas concrete and tangible, and Hands-on drawings helped move theory to practice more than lectures.

These results are consistent with more general studies of active learning in engineering education. Active learning has been demonstrated to increase test scores by about 6% over traditional lecturing, and students in traditional classes are 1.5 times more likely to agree (Freeman et al., 2014). In a pilot study, it was established that standard lectures provided greater per-question scores in certain instances, whereas, in 45% of classes, active learning was equally as efficient (Deslauriers et al., 2019). The students are more inclined towards active approaches, 70-80% of them feel that they contribute to higher-order thinking (Prince, 2004).

The active learning methodology helped to increase engagement, which is consistent with the literature (Jadhav & Deshpande, 2025; Kalyani et al., 2024). The hands-on sessions, including plumbing and electrical layouts, fire safety demonstrations, and presentations/posters, are efficient in filling practical curriculum gaps since they help in integrating theoretical understanding with practical application, as emphasized by (Patil & Kamerikar, 2020). Moreover, the application of virtual reality (VR) as a means of safety training might also facilitate the enrichment of the experiential learning process, as it will be possible to simulate the emergency scenario that would be challenging to recreate in conventional labs.

This approach supports Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) by promoting innovative, inclusive, and equitable learning opportunities, and SDG 11 (Sustainable Cities and Communities) by equipping students with skills to design and maintain safer, more sustainable built environments. It is also possible to consider collaborations with industry stakeholders in future versions to cover the resource gaps, making sure that the methodology is flexible enough and effective in the changing educational environment.

The outcome of this study confirm that active-learning and project-based pedagogies have a significant effect on student engagement, motivation, and acquisition of applied skills in civil-engineering learning. The visualization, safety awareness, and teamwork improvements are evidence of the effectiveness of the implementation of the experiential activity, including plumbing and electrical layout design, the fire-safety demonstrations, and poster presentations in the Building Systems, Safety, and Services (BSSS) course.

The studies covered by Major Learning are Pedagogical Effectiveness, Skill Integration, Sustainability, and Community Awareness. It was found that students showed significant progress in making theoretical knowledge applicable to on-site projects, which proved that the gaps between the classroom and the work experience are bridged by the use of experiential techniques. The design, presentation, and safety modules enabled the development of multidisciplinary thinking and support collaborative problem solving, which are essential industry preparedness properties. Activities aligned with Sustainable Development Goals (SDG 4 and SDG 11) by promoting safe, inclusive, and sustainable building practices. Students became more conscious of their role in society to build safer infrastructures and resilient communities. The model offers a framework that can be replicated by civil-engineering programs that want to comply with outcome-based education (OBE) and meet the demands of employability and ethical-practice requirements.

The implications of the study are direct to the community of engineering education and to the collaboration of academia in the local industry. With the integration of hands-on modules and reflective exercises, institutions are able to produce graduates who are technically competent, socially and environmentally responsible. The research, therefore, fills the gap in industry in the academic community, and it adds to a sustainable system of engineering education to benefit the students, professors, and community at large.

Conclusion

Overall, as evidenced in this case study, the active learning strategies incorporated in the Building Systems, Safety, and Services (BSSS) course have been shown to play a crucial role in improving student active participation, development of practical skills, as well as overall educational performance in the field of civil engineering. The pedagogy would not be a conventional lecture-oriented training exercise as through incorporation of practical experiences such as plumbing and electrical layout drawings, fire safety exercises, and presentation and posters by students on the latest trends in response to the challenges such as smart building technologies and sustainable plumbing solutions and AI-determined safety solutions, the power and authority would be transferred to students and the process would be more interactive. Not only will it result in critical thinking, team work, and practice, but will also adhere to the industry demands with having engineers who will be capable of learning how to operate with complex building systems and safety-related concerns. This interactive structure promotes a greater appreciation and support than is gained through the traditional teaching methodology, which predominantly diminishes to rote learning and passive reception, since the latest and comprehensive studies have shown a lower rate of failures and a higher rate of achievement in active instructional environments.

Despite these strengths, there are weaknesses such as time constraints on the activities, the availability of resources, which reflect areas of improvement. The implementations can be extended to the use of digital tools such as BIM simulations or virtual reality to train safety, which will make them scalable to larger cohorts or online modes. Finally, the study can aid engineering education by offering a model that can be used to improve engineering education in line with the Sustainable Development Goals (SDGs) 4 and 11 to train future civil engineers to create safer and more sustainable communities. It would be even more normalized and possible to perfect this approach by creating longitudinal studies to observe the professional success of the alumni of this course and compare it with other, more common courses, so that it could readily be taught in civil engineering.

This active learning framework can be effectively used by the BSSS course, which underscores the possibilities of its broader application in other spheres of engineering education. The future research will aim at replicating and modifying the project-based and experiential learning model in courses like structural design, environmental engineering, and construction management. This will enable the development of a coherent, interdisciplinary pedagogy that aligns academic learning with industry skill requirements and employability outcomes. When engineering institutions incorporate similar PBL strategies in all their engineering programs, they will be able to develop innovation, teamwork, and problem-solving skills that will be responsive to the changing demands in the engineering field.

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