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From Breadth to Depth: A Transformative Sustainability Learning Approach to Teaching Sustainable Construction

Sundeep Inti[1] and Mavis Bediaku[1]
[1]Illinois State University

Current pedagogies in sustainable construction education often emphasize theoretical coverage of numerous topics under the motto "breadth as strength", a pattern that can reduce student engagement and limit the development of practical competence. Addressing this gap, this study introduces a pedagogical shift that prioritizes student engagement by emphasizing "depth as strength" while still maintaining essential breadth. A teaching framework was developed using the Transformative Sustainability Learning (TSL) model as the foundation and enriched with Kolb's Experiential Learning Theory and Keller's ARCS motivational model. TSL integrates the cognitive (head), experiential (hands), and affective (heart) dimensions of learning, and the incorporation of Kolb and ARCS provided a strong pedagogical basis for intentional activity design and sequencing. The framework was applied to teach indoor air quality (IAQ) within a construction management sustainability course, combining traditional instruction with hands-on testing of pollutants from building and household materials, followed by guided discussions and reflective reporting. Implemented over five semesters, analysis of student reflections showed that most participants found the approach highly effective, describing it as thought-provoking, engaging, and emotionally meaningful. The results suggest that this framework can be adapted to other theory-based courses to enhance student engagement and support deeper learning.

Keywords: Sustainable Education, Transformative Sustainability Learning, Experiential Learning, Indoor Air Quality

Introduction

Imagine stepping into a classroom prepared to teach concepts critical to students' careers and societal progress. Students, drawn by the course's engaging title and description, begin with enthusiasm and curiosity. Yet, as the semester unfolds, that initial excitement often wanes, expectations diverge, engagement diminishes, and a disconnect emerges between the instructor's efforts and students' connection to the material. This disconnect is particularly common in sustainable development (SD) courses, especially within construction management (CM) (Lambrechts et al., 2013).

The integration of sustainability concepts in CM programs initially occurred horizontally, with selected topics incorporated into assignments or projects within existing courses. However, growing industry demand for sustainability expertise, along with accreditation requirements from organizations such as ABET and ACCE, has led many institutions to vertically integrate sustainability by offering it as a standalone course (Lim et al., 2015). These sustainability courses are typically delivered as theory-based classes and often lack a laboratory or hands-on component (Lim et al., 2015). A common feature of such courses is the use of sustainability rating systems, and Rahat et al. (2023) report that nearly half of ACCE-accredited CM programs in the United States teach the Leadership in Energy and Environmental Design (LEED) system. Rating systems expose students to a broad range of sustainability topics—including policy, environmental issues, construction practices, engineering, and innovation, helping them build general awareness and understand the broader context (Lim et al., 2015).

However, covering such a wide scope of concepts at a broad level presents significant challenges, particularly for students with limited background knowledge (Ekundayo et al., 2015). In lecture-based sustainability courses where breadth is prioritized, two persistent issues emerge: students may become disengaged due to limited opportunities for active participation, and the expansive content makes it difficult to provide the depth needed for students to retain and apply knowledge in areas most relevant to their future CM roles (Mulder et al., 2015). Addressing these gaps requires instructional approaches that balance broad understanding with deeper learning in CM-specific sustainability practices while also enhancing student engagement and participation.

To address this challenge, Sipos et al. (2008) introduced the Transformative Sustainability Learning (TSL) framework, which emphasizes the integration of cognitive, experiential, and affective learning—referred to as the "Head, Hands, and Heart." Traditional instruction has largely focused on the "Head," delivering knowledge through lectures, slide presentations, reading materials, and writing assignments (Bediaku et al., 2024). However, the effectiveness of such assignments is increasingly questioned in the age of generative AI tools, prompting a shift toward more interactive and applied learning strategies. Experiential or "hands-on" learning remains limited in sustainability education due to constraints such as scarce resources, restricted class time, and limited instructor expertise in designing experiential activities. Although some studies have explored game-based or project-based approaches (Bediaku et al., 2024.), these efforts are isolated and not systematically embedded in CM curricula. The third dimension "Heart" is more complex to embed in curriculum design and often ignored. In line with the above discussion, this study aims to:

I. Develop a teaching framework that applies the TSL model to integrate cognitive, experiential, and affective learning in sustainability-related CM courses, with the overarching goal of improving student engagement and supporting instructors in designing more effective sustainability curricula.
II. Demonstrate the application of this framework through an example that illustrates how breadth and depth can be balanced within a sustainability course, offering instructors a practical model for curriculum planning.

Methods

Objective 1: Operationalizing the TSL Model for CM Sustainability Education

While the TSL model recommends integrating cognitive, experiential, and affective learning in sustainability courses, questions remain about the appropriate sequence for these domains and the types of activities that should be incorporated into each—particularly within CM curricula. This study addresses these questions by drawing on two classical theories: Kolb's Experiential Learning Theory (1984) and Keller's ARCS model (1987). Together, these frameworks guide the identification of an effective sequence, and the development of pedagogical strategies tailored to the CM student body.

Kolb's Experiential Learning Theory (1984) posits that knowledge is constructed through two interrelated processes: grasping experience and transforming experience. Experience can be grasped in two ways—either through learning concepts via reading or lectures, referred to as Abstract Conceptualization (AC), or through Concrete Experience (CE), where students directly see, touch, or engage with a phenomenon. Once preliminary understanding is established, knowledge is transformed through Active Experimentation (AE), in which students apply what they have learned in real or simulated contexts, or through Reflective Observation (RO), where they reflect on experiences such as field trips, demonstrations, or case studies. In the context of the TSL model, the processes of grasping information align with the cognitive domain, while the processes of transforming experience correspond to the experiential domain. However, because Kolb's model includes two modes of grasping and two modes of transforming, it produces four possible learning pathways as shown in Table 1 (Accommodating, Diverging, Converging, and Assimilating). Determining which combination and sequence best fits CM curricula remains an important instructional question.

Table 1: Kolb's Experiential Theory, various learning styles and factors influencing the learning style (Figure created based on the Kolb 1984 and Kolb et al. (1999)).

	Experience	Transformation	Learning Style	Factors Influencing the Learning Style				
				Personality Type	Educational Specialization	Professional Career Choice	Current Jobs	Adaptive Competencies
Experiential Learning	CE	AE	Accommodating	Extroverted Sensing	Business and Management	Management, public finance, educational, and business	Executive jobs	Action skills: leadership, initiative, and Action
		RO	Diverging	Introverted Feeling	Arts, History, Political Science, English, and Psychology	Social Service, arts, & communications	Counseling and personnel administration	Valuing skills: relationship, helping others, and sense-making
	AC	AE	Converging	Extroverted Thinking	Physical Sciences and Engineering	Technology, Economics, and Environment	Technical jobs (engineering & production)	Decision skills: qualitative analysis, use of technology, and goal setting
		RO	Assimilating	Introverted Intuitive	Economics, Mathematics, Sociology, and Chemistry	Sciences, information, or research	Information jobs, planning and research	Thinking skills: Information-gathering, information-analysis, and theory building

CE = Concrete Experience, AC = Abstract Conceptualization, AE = Active Experimentation, RO = Reflective Observation

Kolb et al. (1999) identified several factors that shape an individual's learning style, including personality, educational specialization, career choice, job roles, and adaptive competencies. As summarized in Table 1, these factors strongly influence both the preferred learning style and the sequence in which learning activities are most effective. For students in CM and related technical fields, the evidence points toward a converging learning style, which blends abstract conceptualization with active experimentation. According to Kolb et al. (1999), students with a converging style prefer experimenting with new ideas, simulations, laboratory assignments, and practical applications. Therefore, teaching in this style provides a balance between theory and practice, giving CM students the opportunity to apply theoretical concepts in a simulated construction environment. This learning style is commonly associated with science- and engineering-based specializations, technology-oriented career paths, and job roles that require problem-solving, technical decision-making, and hands-on application—all characteristics that closely align with the CM student profile. Recognizing this alignment reinforces the need for pedagogical approaches that intentionally integrate conceptual understanding with opportunities for practical experimentation.

Within the TSL framework, the affective domain is strengthened through the application of Keller's ARCS motivational model (Attention, Relevance, Confidence, Satisfaction) (Keller 1987). Keller's framework provides a structured way to enhance students' motivation and emotional engagement—key components of affective learning. The ARCS model supports the affective dimension of TSL in several ways. It helps capture students' attention through novelty or unexpected elements. It ensures that course content and activities feel relevant to their personal experiences and future CM careers. It builds confidence by helping students recognize how their efforts lead to meaningful learning. Finally, it promotes satisfaction by designing learning experiences that are enjoyable and engaging. Integrating these motivational strategies into sustainability instruction helps create a learning environment where CM students feel more emotionally connected to the material. Figure 1 shows the study framework by integrating TSL, Kolb's Experiential learning theory, and Keller's ARCS theory.

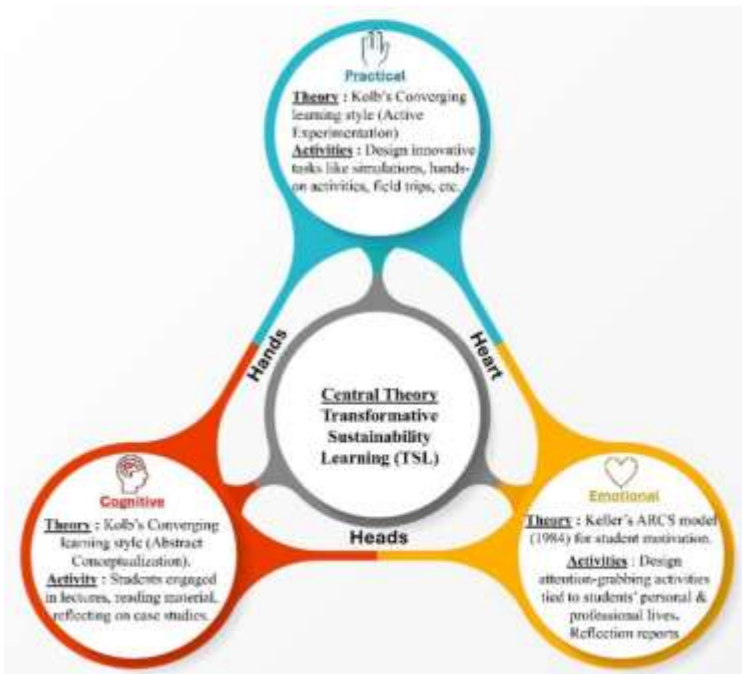

Figure 1. Proposed Pedagogical Framework Integrating TSL Framework ,Kolb's Experiential Learning Theory, and Keller's ARCS Model.

Objective 2: Demonstrating the Framework in a Sustainability Course

The second objective of this study is to demonstrate how the proposed framework (Figure 1) can be applied within a sustainability course to prioritize student engagement while also balancing breadth and depth without compromising either dimension. To illustrate this, the framework is implemented using Indoor Environmental Quality (IEQ)—one of the major topic areas commonly included in CM sustainability courses. IEQ is a critical component of sustainable building design, directly influencing occupant health, comfort, and productivity. Its importance is reflected in the LEED rating system, where IEQ receives the second-highest weighting after Energy and Atmosphere in the criteria for construction of new buildings (LEED v4.1 Guide).

The IEQ category encompasses a broad range of concepts that can be grouped into four key areas: thermal comfort, acoustic comfort, lighting comfort, and indoor air quality (IAQ). While the first three areas are typically addressed by architects and engineers—requiring CM students to develop only foundational awareness—IAQ represents a domain where construction managers have direct and meaningful influence. CM practitioners make decisions related to materials and methods, site practices, ventilation during construction, and worker exposure management, all of which significantly affect IAQ during both construction and occupancy phases. Because of this direct involvement, IAQ is an appropriate and necessary depth topic for CM students, enabling them to make informed decisions that support both environmental performance and occupant well-being. The relevance of IAQ extends beyond professional responsibilities. Research shows that individuals spend approximately 90% of their time indoors, with even higher proportions in colder regions such as the Midwest (US EPA, 2025). Indoor environments often contain higher concentrations of pollutants than outdoor settings due to emissions from cleaning agents, paints, finishes, tobacco products, and cooking activities, contributing to both acute and chronic health risks (Seals & Krasner, 2020). Thus, IAQ literacy also shapes students' personal decision-making and lifestyle choices.

Moreover, despite the growing body of research on IAQ and its health implications, a notable gap persists in CM education regarding hands-on IAQ monitoring and evaluation. Hebert et al. (2022) found that few undergraduate programs engage students in applying IAQ investigations using building materials, finishes, or cleaning products. Although their study focused on interior design curricula, the implications are equally relevant to CM programs, where students are expected to make informed decisions about materials and site practices. This gap further reinforces the need to select IAQ as the depth topic for demonstrating the proposed framework. The proposed framework is applied to teaching IAQ in a CM sustainability course through three activities designed using Kolb's Experiential Learning Theory and Keller's ARCS motivational model.

I. Cognitive Learning (Head): To equip students with foundational knowledge of IAQ and its significance in sustainable building design, including the health impacts of various indoor pollutants on building occupants.
II. Experiential Learning (Hands): To engage students in hands-on investigation of how commonly used building materials and household products contribute to indoor air pollution, using real-time air quality measurements and controlled testing protocols.
III. Affective Learning (Heart): To develop student awareness of the role of ventilation systems and air filters in maintaining healthy indoor environments.

Activity 1 Cognitive Learning

In this activity, students were introduced to IEQ through lectures on LEED v4.1 prerequisites and credits. The first lecture covered foundational knowledge and was supported by brief case studies. The next lecture focused on the Low-Emitting Materials credit, followed by readings on the health effects of formaldehyde, volatile organic compounds (VOCs), and particulate matter (PM). Students then completed reflection questions to reinforce their understanding of IEQ fundamentals and pollutant impacts. This stage aligns with Kolb's experiential learning cycle by supporting Abstract Conceptualization through lectures, readings, and conceptual explanations.

Activity 2 Experiential Learning

The second activity represents the active experimentation phase of this study, in which students investigated how various building materials and household products influence IAQ. The instructor selected more than ten commonly used finishing materials—such as paints, wood stains, adhesives, and new carpeting—along with household items including cleaners, perfumes, deodorants, and facial tissues. Household items were intentionally included to keep the hands-on experience relevant to students' personal lives and to introduce an element of novelty, aligning with the Attention and Relevance components of Keller's ARCS motivational model. Students worked in teams of four to test at least five building products and five household items. During the testing phase, each product was sprayed or applied within five feet of the air-quality monitoring instruments, and students recorded readings for particulate matter ($PM_{2.5}$ and PM_{10}), CO_2, HCHO, and total VOCs, using the Triplett EPC 175 Air Quality Meter. This activity can be conducted in a standard classroom during regular lecture time, ensuring proper ventilation.

Students followed required safety protocols, including wearing face masks, long pants, and closed-toe shoes. They maintained adequate intervals between tests to isolate the effect of each material on air quality. Baseline indoor and outdoor measurements were collected beforehand to serve as reference points. Building materials were sourced from local suppliers and reflected common market options, and household items were selected based on typical availability in local stores. Because air-quality readings—especially for products like spray paints—can vary widely by brand, the results should not be generalized beyond the specific samples tested.

Step 3 Affective Learning

Following the active experimentation phase, this activity strengthened the affective domain using strategies aligned with Keller's ARCS model. To sustain attention, the instructor displayed all tested materials with their corresponding air-quality data, allowing students to compare unexpected differences in pollutant levels. Relevance was reinforced by having students interpret results using IAQ classification frameworks (Table2) and connect pollutant levels to real conditions in homes, workplaces, and construction sites. To build confidence, students reviewed case studies of LEED-certified buildings and analyzed how ventilation and filtration strategies—such as MERV 2, 8, and 13—support healthier indoor environments. Finally, satisfaction was promoted through a reflective report in which students compared their findings with baseline measurements and proposed actionable strategies for improving IAQ in construction and operational settings.

Table 2: Air Quality Classification Based on PM2.5, PM10.0, HCHO, and TVOC Concentration Ranges

Air Quality	Good	Normal	Seriously Polluted
PM 2.5 Concentration (μg/m^3)	0-35	35-75	>250
PM 10Concentration (μg/m^3)	0-75	75-150	>500
HCHO Concentration (mg/m^3)	0-0.05	0.05-0.1	0.1-5.00
TVOC Concentration (mg/m^3)	0-0.6	0.6-1.8	1.8-9.99

Participants

This study was conducted within a sustainable construction course at the author's university. Participants were primarily senior-level CM students, with some juniors who had already completed the program's required 400 hours of industry experience. As a result, most students entered the course with practical field exposure and some familiarity with sustainability concepts. The activities were implemented across five consecutive semesters (Spring 2023–Spring 2025), involving approximately 130 students, and all findings reflect aggregated insights from these offerings.

Assessment

To evaluate student engagement and learning outcomes, the instructor recorded reflective observations across the three activities, focusing on participation, behavior, and team dynamics. Experimental data from step 2 were compared with expected air-quality benchmarks to verify measurement accuracy. Student reports from step 3 were then analyzed thematically to assess growth in understanding relative to step 1, when students initially demonstrated only basic knowledge of IAQ and pollutant health impacts.

Results and Discussion

Effectiveness of Proposed Framework

Developing this framework using the TSL model and integrating Kolb's experiential learning theory and Keller's ARCS motivational model created a coherent structure for instructional design. Combining these theories with knowledge of student needs and instructor experience provided a strong pedagogical foundation that supported intentional decision-making throughout the course. The framework guided the sequencing of lectures, case studies, material-testing experiments, reflections, and discussions, ensuring alignment with cognitive, experiential, and affective learning goals. This structure enabled more deliberate planning of materials, assessments, engagement strategies, and motivational elements, ultimately strengthening the learning experience. It also offers future instructors a replicable model for balancing breadth and depth, selecting meaningful hands-on activities, and designing sustainability content that is both pedagogically sound and relevant to CM students.

Role of Cognitive Instruction (Head)

Activity 1 instruction and assigned reading materials were designed to build students' cognitive understanding of IAQ, focusing on key pollutants such as PM, VOCs, and formaldehyde. Initial observations indicated that many students lacked prior awareness of these pollutants and their impact on health and building environments. However, the combination of structured instruction, guided readings, and reflective exercises provided a foundation for deeper engagement. While some students initially exhibited disengagement during lecture-based instruction, the experiential components of the activity proved essential in overcoming this barrier.

Positive Experiential Learning Experiences (Hands)

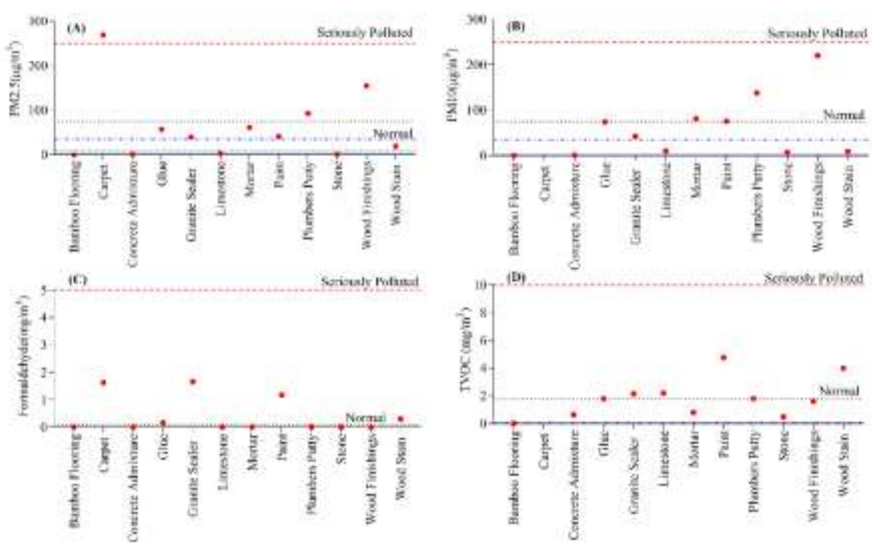

Figure 2. Pollutants (PM2.5 (A), PM10 (B), Formaldehyde (C), and Total VOCs (D)) Emitted from Various Building Items Tested

Students were engaged in collaborative, hands-on testing of various building materials and household products to measure indoor pollutant levels. Working in teams, they tested at least five building and household products. The test results were summarized in Figure 2 (building materials) and Figure 3 (household items). The experiential nature of the activity elicited strong reactions from students, with faculty noting visible surprise when common items—such as deodorants, spray paints, and even carpet samples rubbed together to simulate field conditions—produced unexpectedly high pollutant readings. This surprise often led to spontaneous dialogue among students, as they compared results with their prior assumptions and discussed the implications of their findings. The activity not only deepened their understanding of IAQ but also fostered peer-to-peer learning and engagement. Notably, the testing process was described by students as both informative and enjoyable, adding an element of curiosity-driven exploration that enhanced the learning experience.

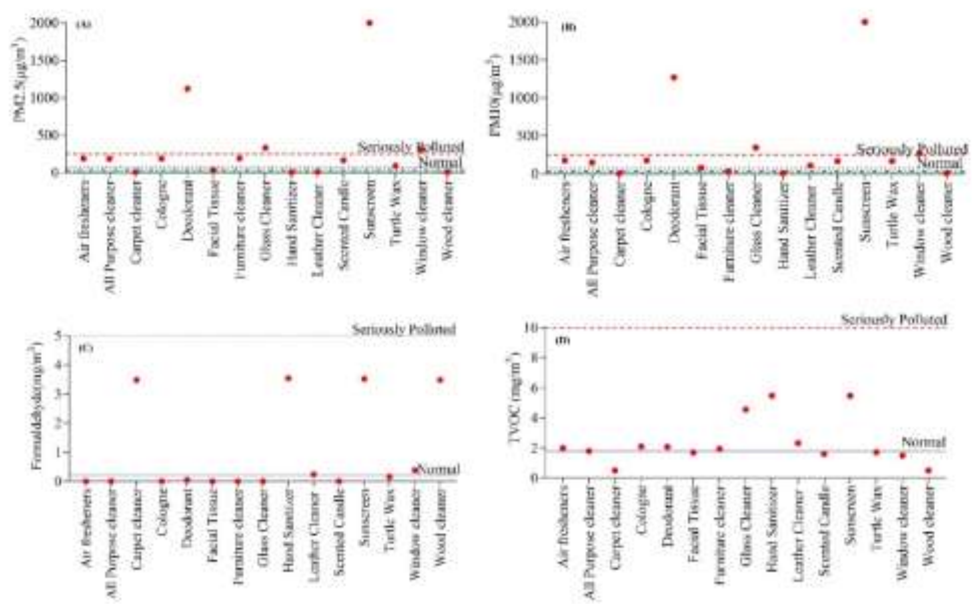

Figure 3. Pollutants (PM2.5 (A), PM10 (B), Formaldehyde (C), and Total VOCs (D)) Emitted from Various Household Materials Tested

Affective Learning (Heart) Outcomes

Student reflections showed that hands-on testing significantly deepened their understanding of pollutants emitted by different materials. Comparing lab-generated data with baseline indoor and outdoor readings, and referencing the pollution levels in Table 2, helped students contextualize results and distinguish whether pollutant levels were good, normal, or severely polluted—insight that did not emerge from instructional content alone. The reflections also revealed strong affective learning: many students described the findings as "*eye-opening*," "*terrifying*," or "*crazy to think*," indicating emotional engagement and value shifts. Students frequently connected the experience to their personal lives, noting changes in attitudes toward household products and construction materials, with comments such as "*this will be in my memory when shopping*" and "*I check the cleaning materials I use*." Themes of environmental responsibility, health awareness, and ethical decision-making suggest that the activity fostered both meaningful data interpretation and a heightened sense of personal and social responsibility.

Transformation in Student Knowledge, Awareness, and Action

The student reflections reveal a significant transformation in attitudes toward IAQ, driven by a pedagogical approach that integrated cognitive, experiential, and affective learning. Students demonstrated a strong grasp of IAQ concepts, referencing pollutants such as VOCs, PM2.5, and formaldehyde, and citing standards like LEED and Cradle to Cradle. One student noted, *"It is good practice to read the labels or test the products and materials that we use in our household,"* highlighting the shift toward informed decision-making. Experiential learning through lab testing and product research deepened their understanding and led to practical recommendations. As one student reflected, *"This research underscores the importance of material selection in both construction and household contexts to improve indoor environmental quality."*

In addition to product awareness, students emphasized the critical role of ventilation in maintaining healthy indoor environments. One student observed, *"Proper ventilation is crucial in maintaining a safe IEQ. When proper ventilation is used, any harmful airborne chemicals or compounds can escape instead of remaining trapped inside."* Another added, *"Ventilation is very important to our living quarters and must be prioritized when it comes to VOCs in the home."* These reflections show that students not only understood the science behind air movement and pollutant dispersion but also recognized its practical implications for occupant health. Most notably, students expressed concern for well-being, environmental responsibility, and a motivation to act—using language such as "imperative," "sustainability," and "educate." One student emphasized, *"General education and awareness of harmful products can help improve the air quality,"* while others advocated for specific actions like choosing VOC-free materials, investing in high-efficiency HVAC filters, and designing spaces with well-placed vents and windows. These insights show that the approach both informed students and empowered them to make healthier, more sustainable choices.

Conclusions

This study aimed to support sustainability instructors in CM programs by improving student engagement and helping balance breadth and depth in course content through a practical pedagogical framework. To achieve this, a model was developed and demonstrated through a case study. The following points summarize the main conclusions.

- This study developed a pedagogical approach grounded in the TSL model and enriched with Kolb's Experiential Learning Theory and Keller's ARCS model to create a coherent instructional structure. The resulting framework is adaptable beyond sustainability education and well-suited for other theory-based courses in CM and related disciplines.
- This study demonstrates the value of applying the TSL framework, which integrates the cognitive (head), experiential (hands), and affective (heart) dimensions of learning in sustainability-related courses, thereby promoting student engagement and supporting the development of expertise in key areas.
- Kolb's and Keller's theories helped guide the selection of course activities—lectures, case studies, hands-on activities, reflection tasks, and class discussions—so that each activity built on the previous one, strengthened students' understanding of concepts.
- The framework enables instructors to design resources and activities that align with their strengths and their students' needs, while still fitting within a regular theory-based lecture format rather than requiring a lab-based course.
- Although this study followed Kolb's converging learning style—moving from cognitive understanding to hands-on experimentation, instructors can adopt any learning style they find suitable for teaching sustainability.
- Sustainability curricula in CM programs often follow a "mile-wide and inch-deep" approach, creating a false sense of expertise among students. While broad coverage is valuable, this study

emphasizes the need to balance breadth with meaningful depth (National Academies of Sciences, Engineering, and Medicine 2020). Building rating systems commonly structure sustainability content, but many topics fall under the responsibilities of owners, architects, and MEP engineers. Only a subset is directly relevant to CM practice, and those CM-specific areas require deeper instructional focus to build real competence.

- The proposed framework was used to teach IAQ within sustainable building design. Students tested various building and household materials, with Figures 2 and 3 showing short-term pollutant spikes that declined over time but still pose concern due to repeated exposures. Their ability to interpret these results and apply IAQ concepts in personal and professional contexts demonstrates that the framework effectively supports sustainability learning, even without specialized lab space.
- The effectiveness of the proposed framework was evaluated solely through student reports and instructor observations. Incorporating additional structured instruments—such as surveys, focus groups, or other validated measures—would strengthen the robustness of the assessment and will be pursued in future studies.

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