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Implementing an Iterative Approach to Crafting a Sustainable Construction Course Curriculum

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Sustainability has deeply transformed 21st-century work and life, emphasizing its critical role in intellectual pursuits and everyday practices. Education is key to bridging the growing disconnect between humans and nature. While sustainable construction is a prevalent topic in construction management curricula, there is still a need for continuous improvement and practical changes to further integrate sustainability into educational programs. As the construction industry shifts toward sustainability, it requires new skills beyond traditional competencies. In response, this paper introduces a systematic, iterative curriculum development model tailored to the Sustainable Construction course within the Construction Project Management (CPM) program at The Southern Alberta Institute of Technology (SAIT). Utilizing technology and artificial intelligence (AI), the research adopts a three-step iterative development model that prioritizes student engagement, knowledge retention, and skill acquisition. To validate the model's effectiveness, the paper presents empirical evidence derived from student feedback, industry stakeholder insights, and classroom observations. This study documents and evaluates the curriculum-design process, offering best practices for integrating sustainability into construction education.

Keywords: curriculum development, experiential learning, teaching methods, pedagogy, construction courses, student-centered learning

Introduction

The increasing demand for sustainability in the construction industry necessitates the integration of sustainability principles into education. Recent studies emphasize the importance of embedding sustainability into construction programs, yet gaps remain in developing comprehensive, iterative curriculum models (Bustamante et al. 2024; Zaki, Rafiq, and Afzal 2023). There is a pressing need for a robust, systematic approach to developing and refining sustainable construction courses within construction management programs (Chi 2009; Szeto and Cheng 2016; Zaki et al. 2023). While existing studies show the positive impact of interactive learning modules on student understanding of sustainable design principles, current literature and practices often focus on isolated aspects of sustainable education (Faludi et al., 2023). This study aims to address these limitations by advocating for an integrated, iterative model that continuously improves the curriculum based on feedback and industry trends. It seeks to fill this gap by providing a detailed example of how an iterative model framework can develop a comprehensive sustainable construction course applicable to other academic institutions. Methods such as HyFlex delivery and AI integration in pedagodgy curruculuim are invatigated. The paper is questioning how the iterative curriculum development process was implemented, the impact of the new curriculum on student engagement and learning outcomes, and the key challenges and successes encountered. To validate the model's effectiveness, the paper presents empirical evidence derived from student feedback, industry stakeholder insights, and classroom observations. Through a combination of theoretical insights and practical applications, this paper offers best practices for integrating sustainability into construction education. The study aims to serve as a resource for educators, curriculum developers, and industry professionals seeking to prepare students for the demands of a rapidly evolving, sustainability-driven construction industry. The course encompasses a range of construction management planning tools, including environmental impact assessments, ecological design principles, low-impact development strategies, and green building certification tools. It also introduces basic concepts of Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA), promoting sustainable infrastructure solutions and providing an overview of Canadian environmental legislation and energy codes. Through theoretical knowledge, case studies, and hands-on projects, students will be prepared to adopt sustainable practices in real-world scenarios.

Integrating Sustainability in Construction into Curriculum

As the construction industry increasingly embraces sustainability, there is a growing need for educational programs to reflect this shift. Embedding sustainability principles into construction education requires not only the integration of environmental and social responsibility but also the development of comprehensive and adaptive curricula (Yu et al., 2018). Traditional construction topics, such as scheduling, contracting, and project management, are beginning to incorporate sustainability concepts, but full curriculum updates remain fragmented (Faludi et al., 2023; Szeto & Cheng, 2016). Integrating sustainability into curricula supports both individual benefits and broader societal goals, fostering critical thinking and interdisciplinary collaboration(Holdsworth & Sandri, 2014). Global efforts, including initiatives like the United Nations' Sustainable Development Goals, have been undertaken to promote sustainability (UNDESA, 2015; UNESCO, 2005), but practical changes in educational systems remain slow (Woodruff, 2006). Strategies for curriculum development have emerged, including interdisciplinary courses, internships, and projects focusing on sustainable materials and energy efficiency (du Plessis C, 2002; Yu et al., 2018), but barriers remain, such as limited faculty familiarity with sustainability principles, resistance to change, and industry disconnect (Woodruff 2006). This study aims to overcome these challenges by presenting an iterative curriculum model that demonstrates how sustainable construction can be integrated into higher education.

Curriculum Development Common Models

Curriculum development refers to the systematic process of creating, implementing, evaluating, and refining educational courses and programs. It is a process that aims to improve the curriculum by using various approaches (Nathani, 2022). The curriculum development process organizes what will be taught, who will be taught, and how it will be taught (Adrian Lam, 2022). Each component affects and interacts with other components. This step-by-step procedure ensures that the curriculum meets the learning needs of students and aligns with educational standards and goals (Nathani, 2022).
As an educator, being familiar with different curriculum development models is essential for making informed decisions. Four models provide structured frameworks for curriculum design, each with a distinct focus:
The *Tyler model*, created by Ralph Tyler in the 1940s, is a well-established approach rooted in the scientific method, and widely used by teachers in North America. The model emphasizes setting clear educational objectives, selecting suitable learning experiences, organizing them effectively, and assessing their achievement (Tyler, 1949). It follows a rational-linear approach, starting with end goals and working backward to ensure all educational activities align with the desired outcomes. In

contrast, The *Taba model* emphasizes a grassroots approach, with teachers creating specific teaching-learning units tailored to their students' needs, gradually building a flexible curriculum framework (Taba, 1962). The *Wheeler model* acknowledges the dynamic nature of curriculum development, incorporating continuous feedback and iterative improvements. This cyclic approach ensures the curriculum remains relevant and adaptable to different learning environments and student needs (Horton, 1968). Lastly, The *Backward Design model* starts by identifying desired outcomes, planning assessments to measure them, and then developing learning activities to achieve these goals. This approach ensures all curriculum components align with the intended results, emphasizing clear goals and a coherent path to achieve them (Mctighe & Wiggins, 1998). These models provide foundational frameworks for educators and curriculum developers, offering unique perspectives on designing, implementing, and assessing educational programs. Their timeless core principles continue to shape contemporary curriculum development and underscore their lasting impact on educational practices.

Research Design and Methodology

This study employed a mixed-methods approach, combining both qualitative and quantitative research techniques to ensure a comprehensive evaluation of the Sustainable Construction course curriculum. The methodology was structured around action research and quantitative analysis, creating a robust framework for iterative curriculum development that integrates technological advancements and empirical evidence (Symonds, 2016). The research design was conceptualized using a three-step process: Planning, Implementation, and Evaluation. The *Planning stage* focuses on laying the foundation for the study through case and model selection, as well as formulating research questions including key performance metrics to evaluate the model. Next, the *Implementation stage* involves data collection and analysis. Finally, the *evaluation stage* focuses on reporting the findings and deriving actionable insights, highlighting key lessons learned and recommendations for future curriculum development. The study area and research methods and tools are discussed under this section. Figure 1 illustrates the reseaerch design and methods, highlighting the structure and techniques used in the research as conceptualized by the author.

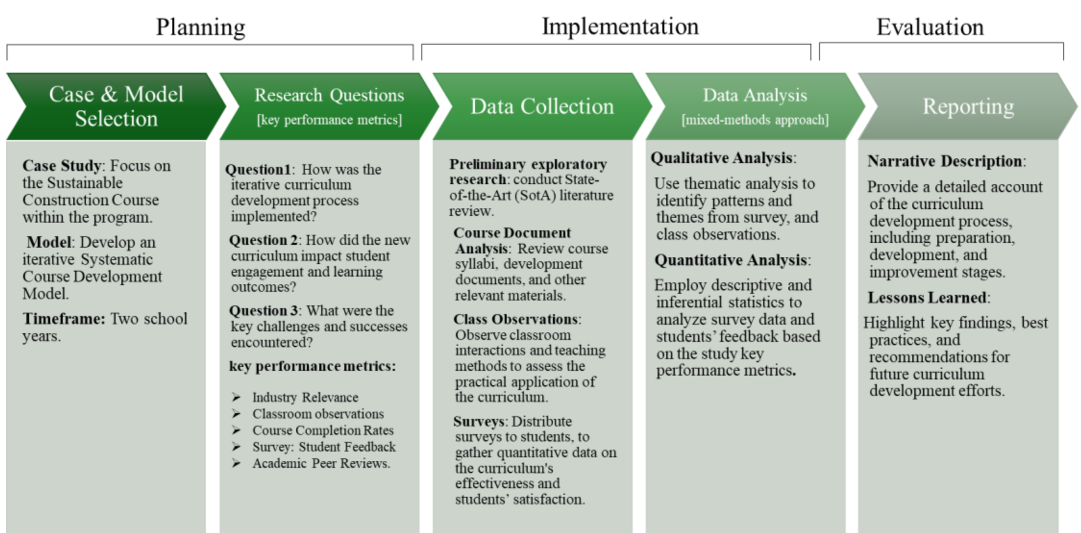

Figure 1. Research design and methodology. By Author

*Study area and model selection*_ The researcher conducted the study within the Construction Project

Management (CPM) program at SAIT in Canada. The research focused on developing and employing a model for the curriculum development of the Sustainable Construction course, which is a core component of the CPM bachelor's degree program, offered to fourth-year students. This course is designed to equip students with critical skills in sustainable construction practices, in response to the growing demand for sustainability in the construction industry. SAIT, recognized for its applied learning approach and industry-focused programs, provided an ideal environment for this study. The course includes a wide array of topics, from environmental impact assessments and green building certifications to life cycle assessments and low-impact development strategies

*Key performance metrics_* To address the research questions and assess the curriculum development model's effectiveness, the researcher used five key metrics: (1) analyzing SFQ (Students Feedback Questionnaires) results to ensure the course aligns with industry needs and trends, (2) collecting feedback from industry professionals via the Industry Advisory Committee to validate course content relevance, (3) involving faculty and peers in the five-year review cycle to meet higher education standards and improve the curriculum, (4) conducting classroom observations to monitor accessibility, student engagement, and overall effectiveness, and (5) performing grade distribution analysis to identify patterns, evaluate learning outcomes, and highlight areas for improvement.

*Research methods_* The study follows an action research method, an iterative, reflective process commonly used in educational settings to improve teaching practices. Action research involved a cyclical process of planning, acting, observing, and reflecting. This allowed for continuous feedback and adaptation throughout the curriculum development process (Clark et al., 2018). To complement the qualitative findings, quantitative data were gathered through the Student Feedback Questionnaire (SFQ), which provided empirical insights into student satisfaction, engagement, and learning outcomes. The SFQ results guide instructional practices by helping educators understand the impact of their teaching on student learning outcomes (CADI, 2024). The researcher collected data from 2018 to 2023 through three survey rounds: before the curriculum's redevelopment, during the COVID-19 pandemic, and after the return to in-person learning.

*SFQ interpretation_* The SFQ were a key tool for evaluating the effectiveness of the Sustainable Construction course curriculum. These standardized surveys, administered at the end of each semester, gathered student perspectives on various aspects of the course, including content delivery, engagement, collaboration, and assessment methods. The SFQ results were measured on a Likert scale, ranging from "Strongly Agree" to "Strongly Disagree," allowing for quantitative analysis of student satisfaction and engagement levels. Charts display the frequency of responses with calculated averages range from a maximum of 4 for Strongly Agree to a minimum of 1 for Strongly Disagree, with comparisons available at multiple levels. The comparisons of averages across various levels (A) offer a comprehensive overview of the data (CADI, 2024):

- CRN average: The average responses for the question specific to the CRN (A1).
- CRN-instructor average reflects the average response for the CRN-Instructor question (A2).
- Course average: The average of responses for the question across all sections (A3).
- School average: The average response across all CRNs delivered by the school (A4).
- SAIT average: The average of responses for the question across all CRNs (A5).

*Population Sample Requirements_* The study included students from 2018 to 2023, with class sizes ranging from 28 to 42. To validate the Student Feedback Questionnaire (SFQ) in line with SAIT's policy, at least 20% participation (a minimum of seven students per semester) was required. To address biases and low participation, the researcher administered additional quarterly surveys to gather feedback from students in both traditional and HyFlex environments. These surveys were conducted anonymously and confidentially to encourage honest responses about course content, teaching methods, and student engagement. Casual class observations and discussions on student satisfaction were also incorporated.This multi-faceted approach ensured reliable data collection process, including only SFQ results aligned with observations and feedback while excluding any unreliable or inconsistent data.

Artificial Intelligence (AI) _ AI integration as a teacher assistant (TA) has the potential to streamline operations, create dynamic learning environments, and provide personalized educational experiences (Johnson 2023). To leverage AI effectively, it is crucial to establish a clear framework guiding its use, ensuring interactions with AI yield constructive outcomes rather than confusion (GSIS, 2024). AI streamlined operations and supported personalized learning in the Sustainable Construction course. It helped develop class lessons, rubrics, and assessments, and analyzed student performance data to identify strengths and weaknesses, enabling targeted feedback and precise interventions.

*Reporting*_ Lastly, a comprehensive documentation and evaluation of the experimental processes and outcomes is conducted each semester that aim to identify best practices and lessons learned. This reflective practice ensures continuous improvement and effective knowledge sharing within the educational community.

*Ethical Considerations*_ The study received approval from the Research Board of Ethics (REB) at the institution ensuring confidentiality and conducting research that respects the rights and well-being of individuals and groups, the researcher upholds these ethical standards.

Results and discussion

This section addresses the design and implementation of the iterative curriculum development model, analyzes key metrics supported by student data to evaluate the developed curriculum's impact on student engagement and learning outcomes, and discusses the challenges and successes encountered.

Systematic Iterative Three-Step Model for Curriculum Development

The sustainable construction course requires a structured and flexible approach to ensure that the curriculum remains adaptable, relevant, and aligned with both educational goals and the evolving needs of the construction industry. The newly developed model draws from the Tyler Model's emphasis on clear educational goals, incorporates teacher input and flexibility from the Taba Model, and uses continuous feedback and iterative improvements from the Wheeler Model. Desired outcomes and assessment planning are guided by principles from the Backward Design model. The curriculum development process followed a systematic, three-step iterative model: Preparation, Development, and Improvement:

*Step one: Preparation*_The process starts with reviewing the existing course syllabus and literature on sustainable construction education.The goal is to assess current trends, identify gaps, and align the curriculum with industry demands.This foundation helps set clear educational goals for the course.

*Step two: Development*_ In this phase, a new course framework was designed, guided by SMART criteria (specific, measurable, achievable, relevant, time-bound). The content was systematically organized, focusing on interactive learning, practical applications, and student engagement. The structure ensured a coherent flow of lessons, allowing students to progressively build skills in collaborative learning environments and discussion-based sessions, keeping them involved and motivated. A detailed schedule for course delivery was then planned, optimizing pacing and sequencing to enhance student engagement and learning outcomes.

*Step three: Improvement_* This final phase involved continuous feedback from students, faculty, and industry stakeholders to refine the course. Their insights helped improve content, teaching methods, and ensure relevance to industry trends. Iterative updates were made based on this input, keeping the curriculum dynamic and effective in preparing students for careers in sustainable construction.

Key metrics are used and analyzed to assess improvements after each iteration, identifying areas of success and opportunities for further enhancement. Figure 2 provides a visual overview of the model, showing its development, key elements, and how it functions through each step to create and maintain the course curriculum.

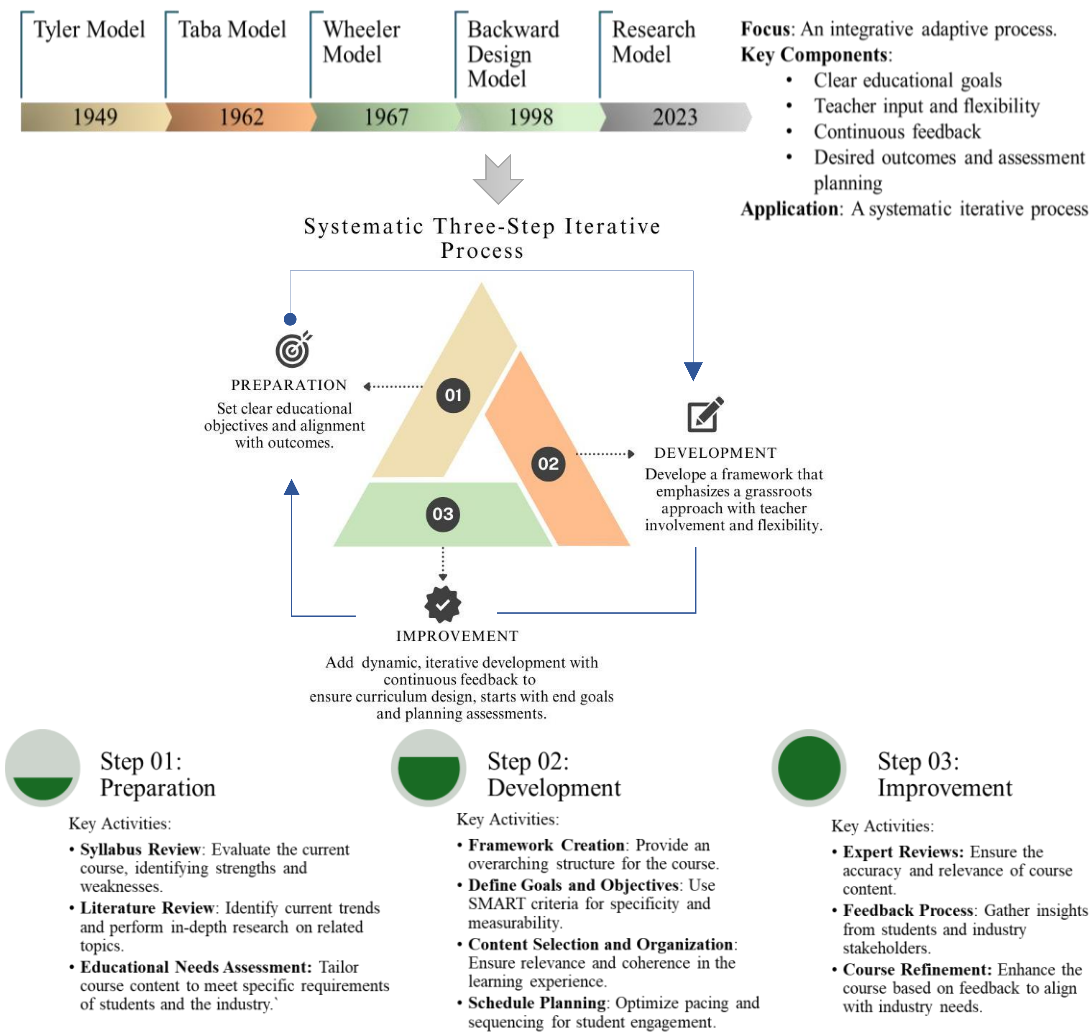

Figure 2. Systematic Iterative three steps Model. By Author

New Curriculum Impacts on Student Engagement and Learning

This section evaluates the impact of the new curriculum on student engagement, satisfaction, and learning outcomes using data from SFQ surveys (2018–2023), classroom observations, and Industry Advisory Committee insights. Survey response rates were 56% (2018–19), 38% (2020–21), and 42% (2022–23). Quantitative analysis focused on four criteria: course resources (C1), student engagement (C2), collaboration (C3), and grades/assessment access (C4). Results showed increased satisfaction over the first two years, with steady improvements in grade accessibility aligning with learning objectives. However, a decline in communication and collaboration was observed during the COVID-19 period. Figure 5 and Figure 5 illustrate trends in students' satisfaction. Figure 5 shows an overall summary of SFQ results, highlighting the four key criteria and their average of responses levels across the years 2018-2023.

Pre-Development Feedback (2018-2019) _ The SFQ survey responses for the open ended questions from 2018-2019 revealed several shortcomings in the existing curriculum. Students expressed concerns about the course's relevance, noting that the content lacked alignment with real-world scenarios. Many found the theoretical knowledge difficult to apply in practical settings, which reduced the perceived value of the course. As a result, there was widespread questioning of the overall usefulness of the curriculum in preparing students for their future careers. In response, a new curriculum model was developed to address these issues, incorporating practical applications and industry alignment..

*Post-Development Feedback (2020-2023)*_ The redesigned curriculum aimed to better equip students with the skills and knowledge necessary for professional success. SFQ surveys from 2020–2023 provided mixed feedback, reflecting both the curriculum's improvements and challenges arising during the COVID-19 pandemic. Many students appreciated the curriculum's stronger emphasis on real-world applications, reporting enhanced preparedness for professional roles. However, some struggled with the rapid pace of updates during the pandemic, affecting their learning experience. The introductiaon of HyFlex classes, combining face-to-face and online learning, had varied responses. Most students appreciated the increased flexibility, allowing more time for work and study, while others found the online format less engaging. Complaints decreased once students returned to in-person classes, with many reporting improved communication and overall effectiveness, making the learning process smoother and more satisfying.

Key Challenges and Successes

The research identified key challenges and successes in the curriculum development process. Overcoming outdated content and student resistance to change, particularly with technology integration, was a major challenge. Resource limitations, such as time constaints and funding, also hindered managing software and course updates. The COVID-19 pandemic further disrupted communication, leading to lower student engagement. Despite these challenges, the new curriculum achieved several key successes. It increased student engagement through interactive, practical learning experiences. The alignment of the curriculum with industry standards ensured that graduates were well-prepared for careers in sustainable construction. Upon returning to campus, most students appreciated the gradual transition with HyFlex delivery, which offered flexibility for balancing work and study. Some, however, found the online format less engaging and more challenging. The integration of AI as a teaching assistant streamlined operations and enabled more personalized educational experiences. Additionally, instructor efforts to adapt the curriculum to real-world industry needs contributed to enhanceresisd learning outcomes and overall satisfaction.

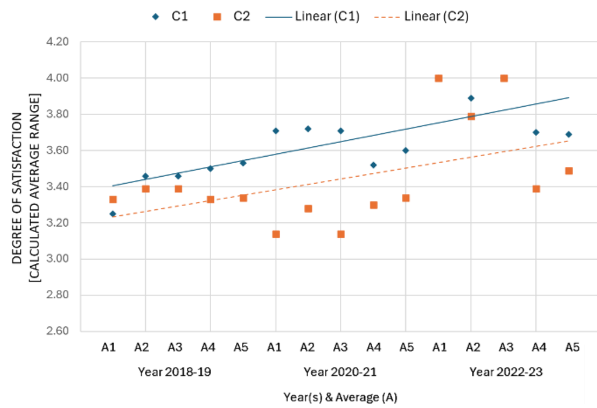

Figure 3. Trend lines and scatter plot show imporoved students' satisfaction in Delivery of course resources and evaluations (C1), and Communication between the instructor and students (C2).

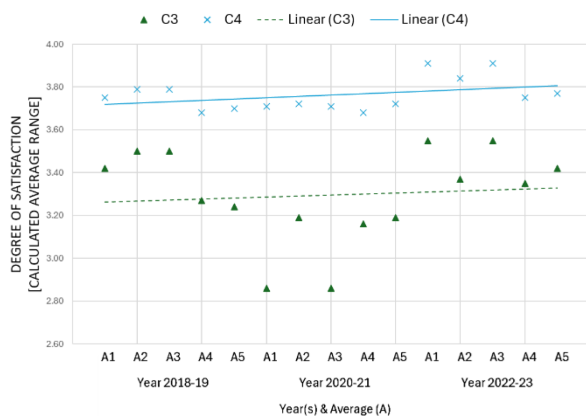

Figure 4. Trend lines and scatter plot shows overall steadiness in students' satisfaction for: Enabling student collaboration(C3), and Providing students with access to their marks(C4).

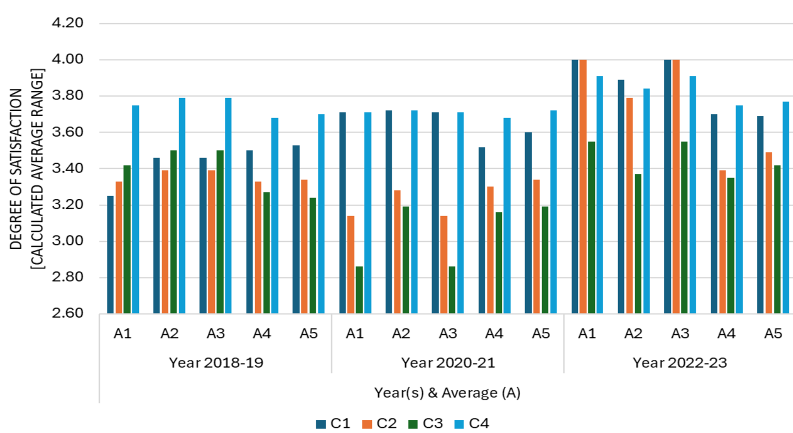

Figure 5. Summary of SFQ Results: Highlights the 4 key criteria (C) and their model average (A). All charts developed by Author based on data from CADI 2024.

Conclusion

The study highlights an iterative development model in shaping SAIT's Sustainable Construction Course into a curriculum that effectively bridges educational goals with the evolving demands of the construction industry. The model is based on a cyclical process of planning, acting, observing, and reflecting. This allowed for continuous feedback and adaptation throughout the curriculum development process. By incorporating well-defined key metrics, the course has been refined to balance theoretical knowledge with hands-on training, leading to improved student engagement and readiness for real-world challenges. Despite challenges posed by rapid curriculum updates and the COVID-19 pandemic, the iterative approach has significantly improved learning outcomes and ensured that the curriculum remains aligned with industry standards. The integration of AI-assisted instruction and the HyFlex model has become a necessity to further enhance the learnin g experience, offering flexibility and personalization that cater to diverse learning styles. Further investigation and future research are needed to explore these aspects in more detail, as well as to expand the course's interdisciplinary reach by incorporating insights from environmental science, policy, and economics. Looking forward, this approach could serve as a blueprint for other institutions aiming to integrate sustainability into their curricula. With the ever-growing emphasis on sustainable practices globally, education systems must stay agile and responsive, positioning students to not only meet but lead future industry standards.

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