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Integrating Smart City Concepts in Civil Engineering Education through Experimental- Centric Pedagogy

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WIP: Integrating Smart City Concepts in Civil Engineering Education through Experimental-Centric Pedagogy

Introduction and literature review

As the urban population grows, the need for a sustainable and Smart City (SC) becomes an important necessity for our future [1]. SC uses new technologies to improve life quality and enhance environment terms, including smart transportation systems, sustainable urban planning, and green buildings [2]. The COVID-19 pandemic has shown the importance of resilient urban planning, emphasizing the need for Smart Cities to maintain social services during crises [3]. Despite the dependence of our future on SC technologies, they are not included in the civil engineering curriculum, which causes a gap between education and real-world upcoming needs.

To make civil engineers capable of building SC they should get familiar with new technologies and experience them with hands-on activities so they can engage with real-world applications. The development of SC Technologies in universities needs diverse approaches that engage students from various fields, such as civil engineering, architecture, computer science, and social sciences [4]. Also, incorporating projects that focus on sustainable energy management including solar power energy, enhances students' understanding of SC frameworks [5] and integrating cognitive computing and data analytics into civil engineering education can create a learning atmosphere that increases student engagement in SC Technologies [6].

To fill the mentioned gap, the Experimental-Centric Pedagogy (ECP) framework which uses hands-on, experimental learning techniques can be used to implement SC in the civil engineering curriculum. ECP is way ahead of traditional lecture-based education by engaging students in hands-on activities to learn how to solve problems using their knowledge. Such activities not only enhance technical skills but also allow students to appreciate the socio-technical dynamics of urban planning [7]. By implementing the ECP framework into civil engineering education, students will be prepared to deal with designing and constructing sustainable urban environments [8]. A study mentioned that students value the use of hands-on activities for educational purposes [9].

This paper presents the efforts to integrate SC concepts in civil engineering education using the ECP framework by creating proper modules and mapping them to Bloom's Taxonomy and ABET 1-7 outcomes. The authors introduce hands-on activities and experiments designed to involve students with SC components such as smart traffic systems, green buildings, and other related concepts. The outcome of this implementation will be assessed in two ways: using assessment rubrics by instructors, and pre-and-post questionnaires for students to evaluate their knowledge before and after attending SC ECP sessions. The goal is to provide quantitative data on the effectiveness of integrating SC concepts in civil engineering education to illustrate how this innovative approach improves motivation, problem-solving, and critical thinking capabilities among students besides technical skills. The research question in this study is: How can SC concepts be properly integrated into civil engineering education through the ECP framework to fill the gap between theoretical knowledge and practical application?

Methodology

1- Mapping learning objectives: To integrate SC concepts into the civil engineering education program, the methodology includes mapping learning objectives to the ABET Student Outcome 1-7 and Bloom's Taxonomy. This process will guarantee that created modules align with civil engineering courses while ensuring effective outcomes. The mapping process has the following steps:

- Identify the main topics in the SC concept related to civil engineering: Topics related to civil engineering with societal benefits, such as smart transportation, energy-efficient construction, and the Internet of Things are selected.
- Define specific learning objectives for each topic: Authors try to match learning objectives to different learning levels (remembering, understanding, applying, analyzing, and creating) and affective domains (valuing and responding). Each objective is designed to align with ABET criteria and be relevant to both theoretical and practical knowledge.
- Align learning objectives with ABET Student Outcomes 1-7: It is illustrated in Table 1 for each ABET number.

Table 1- Mapping learning objectives to ABET

Number	ABET description	Objectives
ABET 1	Complex problem-solving	Using analytical skills for SC
ABET 2	Engineering design	Developing sustainable data-based approaches
ABET 3	Communication	Create proper reports and presentations
ABET 4	Ethical and professional responsibilities	Considering social and environmental terms
ABET 5	Teamwork	Developing collaborative skills
ABET 6	Experimentation and data analysis	Using experimental tools for SC scenarios
ABET 7	Acquiring new knowledge	Preparing students to comply with SC Technologies

2- Module Development Process: A structured approach is used to develop an educational module for integrating SC concepts into civil engineering courses. The method of creating these modules has the following steps:

- Finding needs: Find gaps between the current civil engineering curriculum and SC concepts
- Module Design: Each module must fulfill the following items:
  - Introduction to theory: Develop basic knowledge of SC for students
  - Hands-on activities: Introduce software and tools for hands-on activities related to SC concepts
  - Real-world case studies: Define projects for students to involve them in modeling and simulating SC challenges such as urban planning and smart traffic design.
  - Integration with existing curriculum

3- Implementation of Modules: To develop modules and implement them in courses, some steps such as training instructors and creating classroom delivery (Hands-on experiments), must be done.

4- Assessment and Feedback Mechanism: To realize the effect of the SC module on students' knowledge of the SC concept, some assessments must be provided. Evaluations based on generated rubrics and using a self-report survey are selected for this study.

Results and discussion:

To create a comprehensive framework through ECP to improve the knowledge of students on SC, some steps is introduced by the authors for future semesters:

1- Learning objectives: Specific learning objectives are defined to create a logical and structured approach to integrate SC concepts into civil engineering education. These objectives are aligned with Bloom's Taxonomy and mapped to the ABET 1-7 student outcomes to ensure compatibility with modern standards. In Figure 1, the summary of content within Bloom's Taxonomy is illustrated.

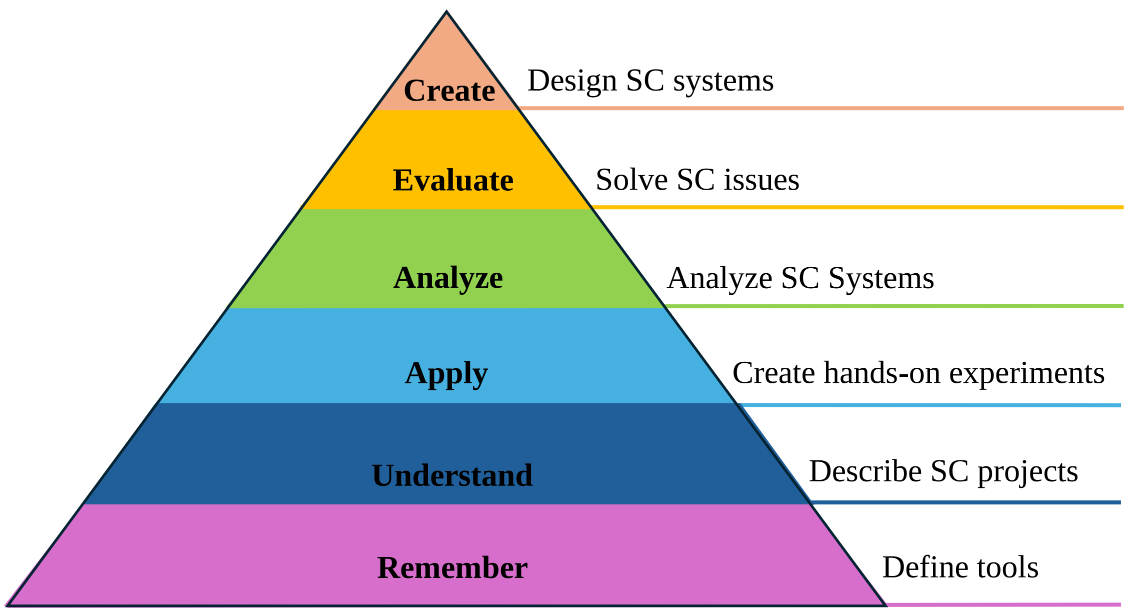

Figure 1- Bloom's Taxonomy graph

- Knowledge (Remember): Define tools, technologies, and experiments used in SC systems such as smart transportation and air quality control. (Mapped to ABET 7: Acquiring and applying new knowledge)

- Comprehension (Understand): Describe the framework of SC projects and their environmental and social impacts (Mapped to ABET 4: Recognizing professional responsibilities and ABET 2: Consider public health, welfare, and safety in engineering design)

- Application (Apply): Create hands-on experiments to collect and examine SC-related data using new technologies (Mapped to ABET 1: Solve complex engineering problems and ABET 6: Developing and implementing proper experiments)

- Analysis (Analyze): Analyze SC systems to find sustainable and optimized solutions (Mapped to ABET 2: Engineering Design and ABET 6: Analyzing and interpreting data)

- Affective Domain (Evaluate): Working efficiently in diverse teams to solve SC issues, considering ethical and social terms (Mapped to ABET 5: Teamwork and ABET 4: Ethical responsibilities)

- Develop (Create): Design innovative SC systems that solve real-world urban challenges using civil engineering disciplines (Mapped to ABET 3: Communicating effectively and ABET 5: Functioning on a team)

2- Module Development: This study suggests three educational modules focusing on SC concept technologies, shown in Table 2. Beside these three modules, a 3D modeling software (like Lumion) can be used by students to model a SC visually including SC components.

Table 2 – Module development

Module name	Objectives	Tools	Activity
Smart Transportation Systems	Teach students to model smart traffic systems with smart control mechanisms	- SUMO (Simulation of Urban Mobility) - VISSIM - Other traffic modeling software	Design and optimize traffic flow for a defined urban area with traffic simulation software
Energy-Efficient Infrastructure	Develop capability in energy modeling and sustainable structure design	- eQUEST - EnergyPlus	Students perform energy efficiency analysis of virtual building models and suggest design improvements to reduce energy consumption.
IoT in Urban Monitoring	Develop IoT-based data collection and analysis skills in urban planning	- Arduino kits - Environmental sensors: air quality, temperature, and noise sensors	Setup IoT systems to monitor environmental parameters and propose SC solutions based on collected data

3- Assessment Framework: To evaluate the modules' outcomes, a combination of direct assessment and self-report pre- and post-survey is designed, as shown in Table 3.

Table 3 – Assessment framework

Assessment type	Assessment tools	Assessment details
Direct Assessments	Project Evaluations based on rubrics	Students' design projects will be assessed based on technical accuracy, creativity, and compatibility with sustainability principles.
Indirect Assessments	Pre-and-Post-Test Survey	Surveys measure changes in students' knowledge and attitudes about SC concepts.
Qualitative Feedback	Essays and Discussions	Capture students' perspectives on the learning process through essays and group discussions.

The anticipated outcomes of this WIP report include:

- Increase student knowledge of SC concepts, evaluated by assessment techniques
- Showing the effectiveness of hands-on activities in learning procedures by increasing student engagement in real-world SC challenges
- Developing knowledge, creativity, and problem-solving skills for a sustainable and smart urban environment.
- Suggest recommendations for using the approach for other engineering fields.

Conclusion

This study can fill a critical gap in civil engineering education by integrating SC concepts into the curriculum. By using the ECP framework, students will learn about SC challenges and be prepared to design a sustainable environment. This work helps the field of engineering education by illustrating the effectiveness of experimental learning in preparing students for real-world challenges.

In this study, presented as a work-in-progress report, the authors highlight the potential benefits of integrating smart city concepts into civil engineering education through the ECP framework. It is essential to create proper modules and align them with educational standards. This approach can improve traditional education by teaching students using hands-on experiments, so they can gain the necessary skills for designing sustainable and smart environments. Also, suitable assessment techniques are used to measure the students' knowledge before and after attending the course. Future research will focus on refining the modules, developing their implementation, and evaluating their impact on student knowledge.

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