

# WIP - Development of Critical Thinking in AEC Students Aided by Artificial Intelligence

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**Abstract**—This innovative practice WIP paper describes a pedagogical approach to use generative artificial intelligence (GenAI) to promote critical thinking among students in the fields of architecture, engineering, and construction (AEC). Technology is advancing at an unprecedented rate, impacting many aspects of human interaction. AEC are among the fields experiencing this rapid technological evolution. Since education in these areas is continuously improving and adapting to new technologies, the motivation behind this study is to explore how GenAI can support the development of critical thinking in AEC. The correct use of GenAI as a tool in education is crucial for ensuring that students benefit from its capabilities while retaining their own analytical skills. Recognizing the potential of this technology in the professional world, this study focuses on college-level students in architecture and civil engineering courses to promote critical thinking skills by using GenAI as a complementary tool to enhance learning experience. Harnessing GenAI to cultivate critical thinking skills among students can enhance their ability to tackle complex problems and adapt to technological advancements. The main objective of this ongoing study is to explore the integration of GenAI into the learning process to foster critical thinking skills. To achieve this, students in AEC courses at the Universidad San Francisco de Quito (USFQ) were introduced to a GenAI application to generate summaries of specific themes. Then, students were instructed to engage in three rounds of answers-based questioning to further explore the topic from a critical thinking lens. The instructor provided guidance on formulating questions to encourage reflective and critical thinking. Students reported on their interactions, detailing the path of questions and answers and their viewpoints on the assigned topic at the end of the experiment. After the exercise, researchers administered an open-ended survey to gather qualitative information on student's perspective regarding the impact of the GenAI on their learning process and critical thinking development. Data were collected from students of various academic years and AEC specialties, providing insights into their critical thinking development in different contexts. The study also analyzes potential factors influencing the relationship between GenAI use, academic performance and critical thinking in AEC education.

**Keywords**—AI education, critical thinking, engineering education, disruptive pedagogies

## I. INTRODUCTION

In recent years, the advancement and utilization of artificial intelligence (AI) have been significant in fields such as Architecture, Civil Engineering, and Construction (AEC), offering innovative and efficient

solutions to the challenges that arise in these professions both in the workplace and in education [1], [2], [3]. However, this progress has raised concerns in the educational sphere due to the speed and ease with which AI can perform tasks, potentially limiting the development of critical thinking and learning among students.

An inappropriate use of AI can limit the development of skills and learning in students [4], [5]. To address this concern, researchers conducted four pilot studies at the Universidad San Francisco de Quito (USFQ), targeting students from various subjects within the AEC fields, such as water resources engineering, construction management, structural architecture, architectural design and urbanism [6] [7]. These pilots aim to introduce a pedagogical intervention incorporating GenAI to promote critical thinking and other essential skills [8]. Participating students were exposed to a GenAI app in their learning processes [9],[10]. Throughout three rounds of questioning and interaction with the app, students were encouraged to practice cognitive skills, including interpretation, analysis, inference, evaluation, explanation, and self-regulation [11],[12]. Then, students were asked to formulate questions that would stimulate reflective and critical thinking, thereby deepening their understanding of the topics studied [13],[14],[15],[16].

The results of these preliminary studies suggest that the integration of AI as a complementary tool in the learning process can help students expand and improve their knowledge while fostering critical and reflective thinking skills [17]. By exploring the potential of AI to cultivate these skills among AEC students, this study offers valuable insights into how technology can be effectively leveraged in the educational sphere [18].

Furthermore, it highlights the importance of a reflective and careful implementation of AI in the classroom to ensure a proper balance between access to information and the development of fundamental cognitive skills [19].

## II. BACKGROUND

Technological advancement is rapidly revolutionizing various professional fields, including medicine, construction, mechanics, education, among others [20], [21]. In the academic realm, Architecture, Civil Engineering, and Construction (AEC) stand out as sectors particularly influenced by emerging technology [22] [23]. From the use of new software for design and rendering to innovative technologies like drones and satellites for mapping, and even the use of IA, which positions itself as a relevant tool in the AEC industry, offering new perspectives for learning and skill improvement [24]. In this context, education in AEC has become an area constantly seeking adaptation and improvement, where the integration of artificial intelligence stands out as a fundamental element for training professionals prepared for contemporary challenges [25].

Technological advancement is rapidly revolutionizing various professional fields, including medicine, mechanics, business, education, among others [20], [21]. The AEC academic field has typically stood out for its technological advances [22],[23], from the use of new software for design and rendering to innovative technologies such as drones and satellites for mapping, 3D printing of concrete. Incorporating AI tools in the educational pedagogy offers new perspectives for learning and improving skills [24]. If used correctly, understanding its potential and limitations, AI offers opportunities to improve teaching and learning fostering the development of critical thinking among students [25],[26].

The increasing use of artificial intelligence among students brings into consideration the importance of fostering skills that promote the continued growth and development of knowledge, creativity, and critical thinking [27]. Critical thinking emerges as an essential skill that students, and society in general, must possess [28]. To develop this skill, it must be cultivated from an early age and at all academic levels. This concept encompasses a range of complex skills, including interpretation, analysis, inference, evaluation, explanation, and self-regulation [4]. These skills are essential for addressing challenges in all areas of life, as they are vital for informed decision-making and problem-solving.

Critical thinking assessment has been a topic of debate among academics, and various tests and questionnaires have been developed to measure this skill; for example, the Watson-Glaser Critical Thinking Appraisal test, which seeks to measure skills such as interpretation, analysis, inference, evaluation, explanation, and self-regulation [11]. An aspect of critical thinking is creativity, which is a crucial skill in

the AEC industry. Creativity allows students to approach design problems with originality and innovation [6]. The assessment of creativity can be done through tests that measure divergent and convergent thinking, as well as through artistic self-assessments [29].

AEC education combines theory and practice throughout its curriculum [6]. In architecture, students develop design and structural analysis skills by exploring emerging technologies such as artificial intelligence applied to architectural design [17],[30]. Creativity is combined with technical rigor to shape innovative and functional projects [13]. The relationship between hand drawing and digital tools has been the subject of debate, but recent studies suggest that the use of digital platforms can enhance creativity in the design process [21], [31].

Finally, a challenge in architectural education is the understanding of complex urban phenomena and its multi-scaled variables, such as informal urbanism [32]. GenAI can offer an innovative way to address these educational challenges, allowing students to explore and analyze complex concepts [33]. While in civil engineering, critical thinking is key to provide solutions for multivariable issues, such as project design and planning [15], efficient management of water resources, the integration of sustainable water solutions, which is not only vital to ensure the long-term viability of built structures but also plays a fundamental role in mitigating environmental impacts and promoting resilience to extreme weather events [3]. Creativity also plays a crucial role in finding innovative solutions to design and construction challenges, from optimizing transportation systems to managing water resources and sustainable urban planning [27]. In this sense, the integration of digital tools and creative thinking techniques in the training of civil engineers and architects can enhance their ability to address complex problems and generate effective solutions [34].

The integration of GenAI in the AEC domain has led to various applications, from generating conceptual images to optimizing architectural designs. Tools like Midjourney, ChatGPT, Maket.ai, and Architectures are being used by students and professionals to explore and develop new ideas and approaches in their projects. These platforms offer innovative solutions that facilitate the conceptualization and design of structures and spaces, allowing for greater efficiency and creativity in the architectural and civil engineering design process [35]. The integration of GenAI into the AEC education represents an opportunity to explore new approaches in design and construction. As technology continues to advance, this integration promises to reshape the landscape of education and professional practice in the construction industry [36].

### III. METHODOLOGY

This WIP is an exploratory study that encompasses the results of critical thinking development aided by GenAI in architecture and civil engineering students. During 2022-2023 and 2023-2024 academic years, a pedagogical intervention followed by an anonymous survey was distributed to students enrolled in architecture courses Structures 1 (n=45 students), Structures 2 (n=37 students); and Civil engineering courses Environmental Engineering (n=22 students), Construction Costs (n=16 students), and Construction Project Management (n=18 students). The survey provided to the students included open-ended and multiple-choice questions regarding their perspective about using GenIA to enhance critical and creative thinking. The pedagogical strategy mentioned was implemented across all students enrolled in the aforementioned courses [37]. Participants in different study areas and semesters, addressing various study topics for AI and students such as structures, urban planning, water resources, and sustainable construction.

The pedagogical intervention starts with students having to summarize a short video or reading related to their course content (water management, Lean construction, informal urbanism). Here, the experiment leader advises students to use ChatGPT to summarize the most relevant points of the video script or reading. Then, students select one of the summary points and interact with the GenAI through questions that delve deeper into the topic. This interaction should contain at least 3 rounds of back-and-forth critical thinking questions.

Students reported on the learnings of one of the points of the last answer ChatGPT provided. In 3 sections of the architectural courses, the pedagogical intervention consisted of a practical workshop where students in small groups used GenAI programs such as Architectures, Midjourney, Maket.ai and Kaedim to approach the architectural design through a set of constraints, and were asked to come up with 3 alternatives, reframing the constraints to create adjustments. This also happened with 3 rounds back-and-forth. Once all the respective tasks were completed, students described the route of questions carried out and discussed the topics to verify the depth of learning and the use of GenAI as a tool for the development of skills such as critical and creative thinking.

Finally, a 9 open-questions survey was carried out to evaluate topics such as: their perception of the effectiveness of the activity, the ease of use of artificial intelligence tools, their opinion on how these tools could be improved or expanded in the future and how artificial intelligence helps them enhance skills that develop critical thinking. The survey responses were

content analyzed for common clusters to build themes that determine the students' perception of the use of artificial intelligence and its contribution to the development of critical thinking. To analyze the surveys, the information was processed using Excel. First, all responses to each question were carefully read. Then, the main ideas of the responses were identified and grouped using a color system. Each color represented a specific main idea, and the responses were classified into positive, negative, and neutral categories based on their content. This comprehensive methodological approach allowed for a complete understanding of how GenAI can be used as an effective tool to enhance learning and skill development in the AEC field.

### IV. RESULTS AND DISCUSSION

The results obtained from this study revealed how students perceived and utilized GenAI in the learning process to develop critical thinking skills. It was observed that these tools enabled students to quickly obtain concise and synthesized information. They highlighted that such technologies helped them present the main ideas of a topic clearly and rapidly, as well as summarize information from videos within seconds. Also, these tools stimulated critical thinking by encouraging students to formulate questions and critically assess the information provided, prompting them to delve deeper and question the responses.

Students recognized several advantages of using GenAI as a learning tool, and also a concern regarding the accuracy of the information received. Regarding the use of these technologies in learning, students reported that they allowed them to gain an overview of the topic, facilitating understanding and promoting further research. These tools became useful starting points for initiating research processes and expanding literature reviews. Such tools provided students with an overview of project issues, aiding their understanding of the topics and enhancing their research and comprehension.

TABLE 1: Summary of surveys results

Subject	Main Outcomes
Construction Engineering	Allowed students to obtain concise information and synthesize it
	Helped students understand a topic and identify the main ideas
	Encouraged questioning the veracity of the information
Architecture	Supported the creation of a functional and creative layout design for the project.
	Helped students understand the narrative of the project.
	Offered ideas to further develop the main concept.

<b>Urban planning</b>	Helped understand the topic and its social and economic impacts.
	Allowed students to analyze and propose better solutions.
	Deepening the topic and challenges in information verification.
<b>Water resources</b>	Analyzed and visualized data in an innovative and practical method.
	Encourage students to investigate and understand complex topics.
	Facilitated virtual labs or experiments and helped identify patterns easier.

The results indicate that the use of artificial intelligence as a learning tool offers numerous advantages, including obtaining concise and synthesized information, stimulating analytical thinking, and facilitating the research and understanding process of the topics studied. However, it is important for students to use the information provided by these tools critically and complement their learning with reliable academic sources to ensure the accuracy and truthfulness of the information obtained.

The results indicate that generative artificial intelligence offers numerous advantages, including obtaining concise and synthesized information, stimulating analytical thinking, and facilitating research. However, it is crucial for students to use this information critically and complement their learning with credible sources to ensure accuracy. The study highlighted the potential of GenAI in enhancing critical thinking skills among students in Architecture, Engineering, and Construction. Integration of these technologies has proven effective in delivering concise information, stimulating analytical thinking, and supporting research processes. However, several key points emerged from these results.

Firstly, while these GenAI tools were valued for providing quick and synthesized information, students raised concerns about their accuracy and reliability, underscoring the importance of verifying content with credible sources. This highlights the need for educators to stress the importance of evaluating information, especially in an era of widespread misinformation. Secondly, the use of these technologies in educational settings was positively received as they provided a broad overview of topics and facilitated understanding of complex subjects. They acted as catalysts for research and literature expansion but were seen as complements to, rather than replacements for, traditional learning methods.

Additionally, these tools have the potential to foster critical thinking by prompting students to ask questions and engage in deeper inquiry. Educators can use generative artificial intelligence platforms like ChatGPT to create learning experiences that promote active

engagement and intellectual curiosity. However, it is essential to guide students in formulating meaningful questions and critically interpreting responses to maximize educational benefits. Finally, the study underscores the importance of context and subject matter expertise in utilizing these technologies effectively. While they offer quick access to information, their utility depends on the quality of input and the relevance of responses. Educators must ensure that students understand these tools' limitations and develop the skills to distinguish between credible and unreliable sources. Overall, the findings suggest that GenAI can enhance critical thinking skills in AEC education. However, its integration should be approached thoughtfully, addressing issues of accuracy, relevance, and complementarity with traditional learning methods. By leveraging these technologies as tools for inquiry and exploration, educators can empower students to become independent and discerning learners in an increasingly complex and information-rich world.

## V. CONCLUSIONS

In conclusion, the findings of this WIP study underscore the potential of GenAI as a valuable tool for enhancing critical thinking skills among students in AEC education. The integration of GenAI can provide students with concise information, stimulating analytical thinking, and facilitating research processes. Thus far, more than 100 students from various civil engineering and architecture courses have been surveyed. The results indicate that, when used correctly, GenAI can significantly improve understanding of complex topics and foster the development of critical thinking skills, among other capabilities. However, there are limitations and challenges associated with the use of AI in educational settings. By providing students with opportunities to interact with AI tools in structured learning environments, educators can foster active engagement, intellectual curiosity, and deeper levels of inquiry. There are concerns regarding the accuracy and reliability of GenAI applications. Educators must ensure that students develop the skills to discern between credible and unreliable information and to complement GenAI insights with traditional learning. Also, to successfully integrate GenAI into AEC education requires thoughtful guidance and support from educators. For this ongoing research, the study aims to expand data collection to more architecture and civil engineering classes, measuring learning outcomes with and without the use of GenAI. Future research will focus on collecting data until the end of 2024 and analyzing it throughout 2025. The continuation of this research will involve assessing the impact of GenAI on student learning, comparing it against traditional methods, and exploring additional applications of AI in enhancing educational outcomes. Researchers expect to develop guidelines to develop GenAI pedagogical modules that complement traditional educational practices. This will

help in creating robust frameworks for the effective use of AI in AEC education, ultimately empowering students to become independent and discerning learners capable of navigating the complexities of the modern world.

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