2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC

Host Sponsor UNC Charlotte

Paper ID #50575

From Scaffolding to Collaboration: Civil Engineering Students' Learning Experiences with ChatGPT and Professional Identity Development (WIP)

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Introduction

Generative artificial intelligence (AI) tools such as ChatGPT are changing how students learn and solve problems in engineering education [1]. These tools can act as cognitive partners that provide guidance, feedback, and scaffolding functions that may parallel or even extend traditional forms of peer and instructor interaction [2]. While prior studies have explored how AI influences students' cognitive learning processes [3], few have explored how these experiences shape students' professional development. In civil engineering education, students often face open-ended, complex problems that require both technical skills and reflective judgment and collaboration [4]. Therefore, this study explores how students engage with ChatGPT as a learning partner in a civil engineering course and how such engagement influences their reflections on learning, professional identity formation, and perceived employability. The purpose is to investigate both the learning processes that occur during human-AI interaction and the meaning-making that students derive from these experiences. The following questions guide our study:

1. How do civil engineering students engage with ChatGPT during their learning activities?
2. What learning patterns and collaborative behaviors emerge from student-AI interaction?
3. How do students perceive the influence of AI-assisted learning on their professional identity and employability?

Theoretical framework

This study integrates Zone of Proximal Development (ZPD) [5] and collaborative learning theory (CLT) [5], [6] as the theoretical framework to examine human-AI interaction as both a cognitive and social learning process. The ZPD was developed by Vygotsky to describe the relationship between human learning and development [5]. According to the ZPD, there are two levels of a learner's ability [5], [7]. The first is the actual developmental level, which refers to everything a student can do independently. The second is the potential developmental level, which represents what the student can achieve when assisted by a more knowledgeable other (MKO). The MKO can be someone or something with a higher level of skill or understanding regarding the task at hand. The ZPD refers to the range of tasks that learners cannot complete independently but can accomplish with appropriate guidance or support [5]. Within this zone, a process called scaffolding occurs. Much like the temporary platforms used in construction, educational scaffolding provides the student with the necessary hints, prompts, and frameworks to complete a complex task [8]. As the student gains mastery, this scaffolding is gradually removed until they can perform the task alone. Therefore, learning in the ZPD is not just about memorizing facts. It is about learning how to use the specific tools, languages, and technical symbols of a field to create meaning and solve problems [9]. According to studies [10], [11], AI tools assist students in identifying and operating within their ZPD by providing personalized, real-time feedback that adapts to the student's current level of understanding.

The CLT shifts the focus from the individual mind to the social group [12]. At its core is the philosophy of social constructionism, which suggests that knowledge is not an object stored in a book or a teacher's head, but a socially justified belief reached through negotiation among peers [12]. In this view, knowing something means being able to participate in the specialized conversation of a specific community, such as the community of professional civil engineers. According to CLT, thought is an internalized conversation [12]. Bruffee [12] argues that individuals learn how to think by first learning how to talk with others. They internalize the patterns of dialogue, questioning, and evidence-sharing that they experience during group work. This process leads to re-acculturation, where students move away from being authority-dependent individuals who simply wait for a teacher to give them the answer [13]. Instead, they become knowledgeable peers who understand that authority is something to be shared and negotiated. In a collaborative environment, students must learn to talk each other out of their unshared biases to reach a technically sound consensus [13], [14].

Literature review

The integration of AI in education has evolved from early intelligent tutoring systems [15] to platforms that provide adaptive learning and automated feedback [16]. Today, AI applications in education are increasingly characterized by their ability to personalize learning pathways, diagnose misconceptions, and provide real-time support [2], [17], [18]. These tools function as informational repositories while also facilitating dynamic interactions between AI and human learners. Such interactions can be framed within Vygotsky's ZPD [5], where technology acts as a scaffold, enabling learners to achieve higher levels of understanding and skill than they could attain alone. Therefore, AI can be understood as a tutor as well as a collaborative agent in the learning process [19].

AI in civil engineering education

AI has been used in engineering education. AI tools like ChatGPT can assist students in navigating complex and open-ended problems [20]. They can help decompose problems, generate and evaluate potential solutions, and explain fundamental engineering principles, effectively providing a form of on-demand scaffolding [1]. For example, Ghasem [21] found that integrating AI and machine learning into chemical engineering curricula through tools like adaptive platforms, virtual labs, and intelligent tutors can enhance teaching effectiveness and improve student learning outcomes in the era of Industry 4.0. In addition, Ramos and Condotta [22] noted that chemical engineering students using AI for process design problems showed improved engagement and learning outcomes, with over 90% of them reporting increased engagement and enhanced learning, suggesting iterative refinement and improved conceptual understanding. Moreover, in programming courses, students using code-generating AI shifted their focus from syntax debugging to higher-level logic and architecture, though this sometimes led to gaps in foundational knowledge [23]. Such interactions can support cognitive processes by offloading lower-level tasks, allowing students to focus on higher-order thinking [24].

Within the specific domain of civil engineering (CE) education, the demand for AI integration is driven by the discipline's requirement for students to master complex theoretical concepts alongside extensive practical knowledge [25]. Large language models (LLMs) are uniquely positioned to address persistent challenges in CE education, such as the need for individualized attention and timely feedback in large classrooms [25]. Empirical evidence highlights the effectiveness of these tools in specific CE sub-disciplines. For instance, junior-level civil engineering students utilizing ChatGPT in Construction Surveying and Geomatics saw an overall subject matter knowledge gain of approximately 34%, producing significantly more thorough and detailed responses after interacting with the AI [26].

Beyond general assistance, civil engineering education is increasingly utilizing domain-specific AI applications to enhance technical mastery. In courses such as Concrete Structure Design, AI-powered platforms can analyze students' learning behaviors to provide personalized resource recommendations [27]. Interdisciplinary knowledge graphs have been used to connect scattered engineering concepts, such as material properties and reinforcement calculations, into a coherent and systematic framework. As a result, the proportion of high-achieving students increased from 10.2% to 23.7% [27]. In addition, the integration of knowledge-based expert systems (KBES) has proven effective in bridging the gap between conventional engineering methods and modern computational techniques [28]. In one case study, students developed a Geo-Expert system for soil classification using standard professional systems like AASHTO and USCS, which significantly increased their awareness of systematic knowledge acquisition and improved their problem-solving skills [28].

The strategic evolution of civil engineering education also emphasizes the synergy between AI and other digital technologies, such as building information modeling (BIM) and geographic information systems (GIS) [29]. Multi-level education models have been proposed where undergraduate students focus on foundational IT concepts, while graduate programs utilize AI in project-based learning for smart cities and sustainable development [29]. Preparing students for this workplace requires fostering essential skillsets such as critical thinking, ethics, and a holistic understanding of infrastructure as a network [30]. To thrive in an AI-enhanced practice, students must develop a mindset characterized by adaptability, open-mindedness, and lifelong learning [30].

Despite these benefits, the unique and context-sensitive nature of civil engineering, which prioritizes human health and safety, requires a cautious approach to AI integration [25], [31]. While AI tools can effectively explain procedural tasks like concrete mix design, they often struggle with complex mathematical computations and lack direct access to specific professional manufacturing tables, such as properties for hot-rolled steel [32]. Moreover, a survey of civil engineering students found that while most are confident in their basic understanding of AI, many remain uncertain or neutral regarding the fairness, safety, and ethical implications of its professional use [31]. Because incorrect data can lead to bad structural design with severe consequences, future engineers must be equipped with the critical thinking skills necessary to independently verify and scrutinize AI-generated outputs [30], [33].

Human-AI collaboration in learning

The concept of human-AI collaboration in learning extends beyond tool use to encompass partnership, where the AI and student engage in a dialogic process to construct knowledge [34]. During the collaboration, students learn not only from AI but with it, such as engaging in iterative prompting, critique, and explanation that mirrors peer-to-peer learning [2], [18], [35]. Specifically, Chan [36] documented a cognitive partnership model where students learned to treat the AI as a sounding board, prompting it to argue against their own hypotheses, which deepened their critical reasoning. A study [38] on collaborative writing also noted that students who engage in highly interactive processes with AI-assisted tool can achieve better performance in the writing task. Therefore, the human-AI collaboration process may motivate metacognitive skills as students need to articulate their needs, assess the AI's responses, and integrate feedback into their understanding.

Moreover, scholars [18], [38] suggested that when users perceive AI as a collaborative partner, it can enhance engagement, motivation, and the co-construction of solutions. However, the quality of collaboration is often dependent on the student's ability to direct the interaction. This can lead to a collaboration gap where less proficient learners may become passive recipients rather than active partners [39]. The meaning-making derived from these interactions, how students interpret the role of AI and their own agency, is thereby the key to understanding the impact of AI on learner development and professional preparation.

Professional identity and employability of civil engineering students

Professional identity formation is a critical aspect of undergraduate education, as students who fail to identify with the engineering profession or maintain a sense of belonging are significantly more likely to leave the field [40]. Professional identity is understood as a dynamic construct that integrates an individual's personal world with the collective space of disciplinary cultural forms and social relations [41]. For civil engineering students, the university serves as a primary site where they internalize values, behaviors, and practices characteristic of the profession [40]. Employability in civil engineering is defined as the development of capabilities for successful and sustainable career development [42]. Industry expectations for graduates have evolved. While a technical degree is a prerequisite, employers increasingly seek a triad of components: a good degree, generic skills, and personal attributes such as integrity and initiative [43], [44].

The integration of AI is fundamentally reshaping how engineering students prepare for the workforce. AI-powered tools are increasingly used to enhance core career competencies such as communication, problem-solving, and teamwork [45]. These tools provide adaptive feedback that simulates real-world professional scenarios, which is essential for a labor market where nearly 50% of employees will require reskilling by 2025 [45]. Recent graduates acknowledge that AI improves efficiency in data management but continue to view core engineering judgment and ethical oversight as uniquely human functions [46].

Methods

This study utilizes a qualitative case study design to investigate how students engage with ChatGPT as a learning partner in a civil engineering course and how such engagement influences their reflections on learning, professional identity formation, and perceived employability. A qualitative approach was selected to capture the meaning-making and exploratory talk that occurs during student-AI interactions. The research focuses on the undergraduate students enrolled in a core Rock Mechanics course during the Spring 2026 semester. This discipline requires students to apply reflective judgment to complex, site-specific geotechnical problems where general AI tools often lack a specific professional context.

Data collection is structured around a multi-phase pedagogical design that proceeds through three targeted course assignments and a demographic information survey administered after the final grades are posted. The three assignments are designed to generate behavioral data from conversation transcripts and perceptual data from reflective accounts. The first assignment is a longitudinal task where students use the AI for self-directed exam preparation and post-exam review, allowing researchers to track how exploratory talk evolves as students confront and bridge their own learning gaps. The second assignment focuses on concept decomposition and calculation validation, where students use ChatGPT to verify their independent solutions to a tunnel excavation problem. This generates behavioral data regarding initial scaffolding and the reconciliation of technical dissensus. The third is a summative reflection where students evaluate their semester-long experience, specifically describing how AI influenced their emerging professional identity and perceived employability.

To provide contextual grounding for these findings, a demographic information survey is collected after the course concludes. This survey captures baseline variables such as year in the program, prior AI familiarity, and self-reported engineering confidence. The analysis of all data will be conducted using NVivo software through an inductive thematic analysis to allow categories and themes to emerge directly from the participants' interactions. Throughout this process, researchers identify patterns of convergence and variation to determine how students navigate the authority of AI in relation to their developing professional standards. This study has received IRB approval from the University of the third author.

Anticipated findings and implications

This paper is a work in progress. Inductive analysis of the conversation transcripts is expected to reveal diverse patterns in how students utilize AI as a cognitive tool, ranging from procedural support for calculations to higher-order conceptual problem-solving. These behavioral data may further illuminate the technical limitations students encounter when applying general AI to site-specific rock mechanics problems. Regarding professional development and perceived employability, the study anticipates identifying themes from the reflection papers related to how students negotiate their professional roles and enact agency when navigating misalignment with AI-generated content. These results are expected to clarify how interacting with an AI partner influences a student's emerging engineering judgment and their internal sense of belonging within the civil engineering community. By cross-referencing these reflections with the post-course survey data, the research further anticipates uncovering specific insights into how baseline confidence and prior experience influence students' experience within the context of Industry 4.0. The results are expected to inform the ongoing discussion about curricular misalignment, suggesting where engineering programs might transition toward a model that emphasizes reflective judgment and the mastery of human-AI interdependence. As data collection for the Spring 2026 semester is currently active, the emergent thematic framework and finalized findings will be reported during the conference presentation.

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