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Enhancing Self-Directed Learning with GenAI: A Freshman-Level Engineering Case Study

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Abstract

The transition from structured, teacher-led high school learning to the self-directed learning demands of college is a major challenge for many first-year students, particularly in large freshman courses where faculty–student interaction may be limited. This challenge is further intensified by the rapid rise of generative artificial intelligence (GenAI), which brings both opportunities and concerns for higher education. To promote responsible GenAI use and better understand how first-time-in-college (FTIC) students employ these tools, this study developed a custom AI chatbot (I2CE; a pseudonym used to preserve anonymity) as a self-study assistant for an Introduction to Civil Engineering course. The two-credit course meets weekly for three hours over 10 weeks and covers four modules: (1) an overview of the civil engineering profession; (2) lifecycle of construction projects; (3) essential professional skills for engineers; and (4) professional ethics.

This study aims at examining GenAI usage and student perceptions in a class of 82 freshmen. Data were collected from students using a two-tier survey strategy: pre-course and post-course surveys and weekly "pulse" surveys administered from Weeks 4–10. Response counts were stable across stages (pre: 77; weekly range: 67–82; post: 82). Surveys captured familiarity with GenAI, perceived usefulness, engagement, perceived effectiveness of GenAI-supported activities, usage frequency, and intention to continue using AI chatbots for learning.

Results indicate consistent increases in familiarity, perceived usefulness, and engagement from pre- to post-course. Descriptive cross-tabulations show that higher perceived usefulness aligns with stronger intention to continue use, and higher engagement aligns with more frequent use. Weekly pulse results indicate consistently high perceived effectiveness, with modest fluctuations associated with topic demands. This study contributes longitudinal classroom evidence and a practical evaluation approach for understanding how guided, course-grounded GenAI chatbots can scaffold freshmen's self-directed learning.

Introduction

The shift from high school's structured, teacher-led setting to the greater independence expected in college is a difficult transition for many first-year engineering students. Beginning in the curriculum, students are asked to manage their time, make sense of unfamiliar engineering content, and take more responsibility for how they learn. In large, required freshman courses, the transition can be even harder due to limited instructor-student interaction and the difficulty of sustaining individualized support [1], [2], [3], [4], [5]. For these reasons, helping students build self-directed learning (SDL) readiness is an ongoing concern in engineering education [6].

SDL is widely studied as a significant competency and supports students adapting to the university environment. Recent studies in engineering contexts have shown that SDL can change over semesters and be influenced by course design, the rate of pedagogical support, and the context of learning [7]. Additionally, surveys and evaluations of first-year engineering students noted a shift from self-responsible learning in high school to a need for guided support in university, which was particularly evident during their first year [5], [8]. This evidence has added

to the debate that courses with large numbers of students need special support, which can be extended to improve SDL rather than relying solely on traditional integration.

To bridge this gap, Generative Artificial Intelligence (GenAI) offers a promising technological scaffold. Recent systematic reviews and studies have suggested that GenAI can improve several learning metrics and learner experiences, but the effectiveness is inconsistent, depending significantly on pedagogical design, task type, and classroom implementation [9]. Meta-analysis also pointed to moderately positive impacts in some contexts, while warning of the risk of reduced quality of engagement if GenAI is used as a mechanism to replace thinking [10]. Therefore, literature emphasizes the need to deploy GenAI in a "human-centered" direction and with responsible usage guidelines to limit dependence, information bias, and related academic risks [11], [12]. In the field of civil engineering or construction management, studies have begun to recognize the potential of GenAI in supporting specialized contexts, but at the same time highlight issues of accuracy, content relevance, and the need to "grounding" according to course materials to reduce irrelevant topics responses [13], [14], [15].

Despite the expanding body of research on GenAI in engineering education, existing studies provide an incomplete picture of how these tools function in authentic classroom settings. Much of the current evidence is based on one-time surveys or short interventions, which makes it hard to understand how student usage and experience develop across a semester [6], [9]. In addition, required freshman courses are underrepresented in this literature, even though early experiences may shape students' long-term study habits and technology use [2], [3]. Finally, there is limited classroom-based evidence connecting students' perceptions of GenAI such as familiarity, perceived usefulness, and engagement to practical indicators that matter for SDL, including whether students actually use the tool and whether they intend to keep using it [16], [17], [18].

To address this limitation, this study presents a longitudinal classroom case study of a freshman civil engineering course that integrated a custom, course-grounded GenAI chatbot [19], [20]. Adopting a process-oriented perspective, our research design follows a specific logical trajectory to understand student adaptation [21], [22]. First, the study quantifies pre–post shifts in students' familiarity, perceived usefulness, and engagement with the chatbot. Second, the study investigates the mechanism of these changes by analyzing whether increased usefulness drives the intention to continue using the tool, and whether heightened engagement translates into frequent usage behaviors. Third, the study assesses the weekly effectiveness of the tool, identifying specific pedagogical challenges and benefits as they emerge across different course topics.

Overall, this multi-layered approach clarifies how GenAI can be leveraged to strengthen the self-directed learning readiness required for long-term success in engineering. The study contributes semester-long evidence from an authentic classroom setting, evaluates the linkage between perceptions and self-directed behaviors, and offers practical insight into the temporal dynamics of deploying GenAI in foundational engineering courses.

Methodology

This study examined the integration of a custom, course-grounded GenAI chatbot into a required freshman-level Introduction to Civil Engineering (I2CE) course. To support self-directed learning within the course, an instructor developed a custom, course-grounded GenAI chatbot, referred to here as the I2CE chatbot (pseudonym), was designed to support students' understanding of course concepts by providing explanations, examples, and guidance grounded exclusively in course materials (Figure 1).

I2CE course is a two-credit course offered during the first ten weeks of the semester. A total of 82 freshman civil engineering majors were enrolled in the course and constituted the study population. All participants were in their first semester at a higher-ed institution. Classes met once per week for a three-hour session in a lecture- and discussion-based format. Course content was organized around four core modules: (1) an overview of the civil engineering profession; (2) lifecycle of construction projects; (3) essential professional skills for engineers; and (4) professional ethics.

Figure 1. The I2CE Chatbot

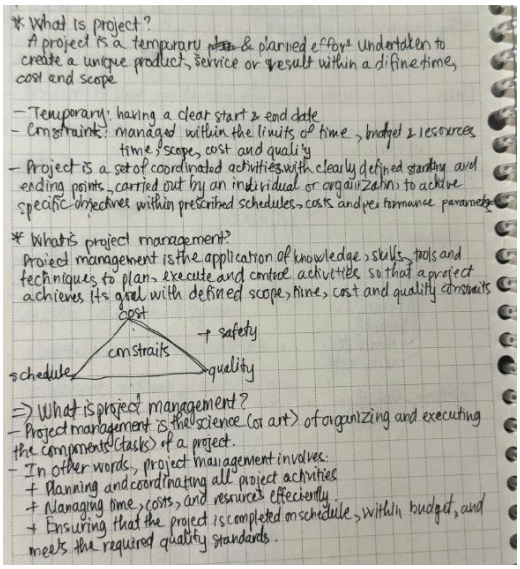
Each weekly class session followed a consistent instructional structure. After a brief instructor-led mini-lecture introducing key concepts, students transitioned into small-group discussions centered on prompts aligned with the week's topic. During these discussions, students were encouraged to use the I2CE chatbot to reinforce their understanding, extend ideas, and clarify confusing concepts. Groups then shared key insights and unresolved questions during a whole-class discussion. The following describes some of in-class activities used in this course.

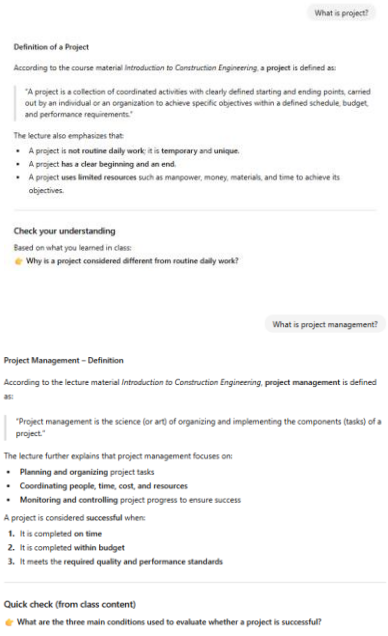
Figure 2 illustrates a representative in-class activity in which the I2CE chatbot was used to support students' conceptual understanding of foundational project management terminologies. In this activity, students were first asked to respond to the prompts *"What is a project?"* and *"What is project management?"* based on the instructor's mini-lecture and assigned course materials. Students recorded their initial responses individually or within small groups, drawing on their initial understanding of course concepts.

After formulating their own definitions, students engaged with the I2CE chatbot to verify and refine their understanding. The chatbot generated explanations grounded explicitly in the course materials, distinguishing between the definition of a project (e.g., a temporary endeavor undertaken to create a unique outcome) and the definition of project management, including its core functions and success criteria emphasized in the course. The chatbot also posed brief

follow-up questions to prompt students to reflect on whether their original responses aligned with the course definitions.

Students then compared their initial responses with the chatbot's explanations, identified missing elements or misconceptions, and reinforced their understanding accordingly before sharing insights during the whole-class discussion.





(a) Students' Responses (b) The I2CE' Responses

Figure 2. Sample Students' and I2CE's Responses

The study adopted an exploratory, longitudinal classroom case study design to investigate how first-time-in-college (FTIC) civil engineering students engaged with the chatbot and how their perceptions of GenAI for learning evolved over time. This study employed two-tiered data collection strategy. Pre-course and post-course surveys were administered to measure overall changes in perceived familiarly, usefulness, and engagement like previous studies that evaluated educational interventions. In addition, starting in Week 4 after students had adapted to college life and AI tools, the instructor administered weekly "pulse" survey at the end of each session. While the pre- and post-course surveys indicate whether a change occurred, the weekly "pulse" surveys captured the dynamic, week-by-week process of GenAI adoption, usage patterns and identified the "muddiest points" of the week for the instructor to address in the following week. This weekly evaluation specifically asked students to rate the GenAI's effectiveness for that particular lesson and provided feedback on their learning experiences.

Table 1 summarizes the students' responses over the course of the semester. Seventy seven (77) students participated in the pre-course survey, while the post-course survey recorded 82 responses. For the weekly pulse surveys conducted from Week 4 to Week 10, the number of responses remained consistently high, ranging from 67 to 82, with no substantial drop in

participation over time. This stable response pattern indicates sustained participant engagement throughout the course and provides a reliable basis for analyzing changes in perceptions across measurement points.

Table 1. Number of Responses across Survey Stages

Survey stage	Pre-course	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Post-course
Number of responses	77	70	67	72	72	76	74	82	82

Results

Changes in Students' GenAI Perceptions Over the Course

Figure 3 summarizes the students' perceptions of GenAI changed from the beginning to the end of the course, focusing on familiarity with GenAI tools, perceived usefulness of the course-grounded chatbot, and engagement in AI-supported learning activities. Overall, results show consistent upward shifts across the three aspects.

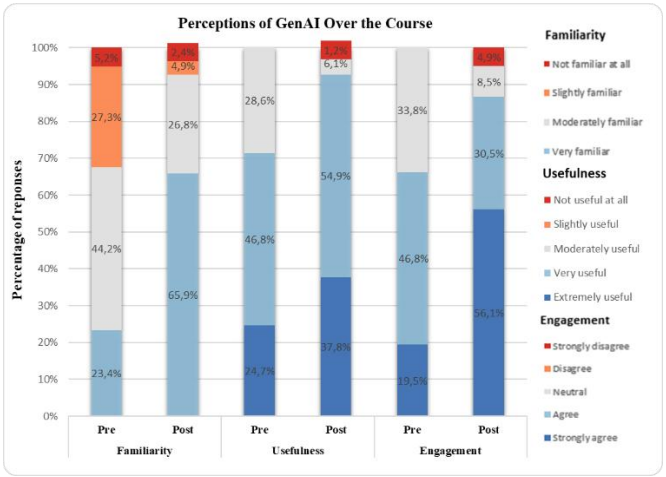


Figure 3. Familiarity, Usefulness, and Engagement (Pre- and Post-Course)

In terms of familiarity, students reported a substantial shift toward the "very familiar" category, increasing from 23.4% pre-course to 65.9% post-course. This gain is largely attributable to a decline in "moderately familiar" responses (from 44.2% to 26.8%) and a marked reduction in "slightly familiar" responses (from 27.5% to 4.9%). Taken together, these shifts indicate that most students completed the course with a strong sense of familiarity with chatbot-based GenAI tools.

Perceived usefulness also increased over the duration of the course, although the change was more moderate than for familiarity. Responses indicate a modest increase after the course in both "extremely useful" (from 24.7% to 37.8%) and "very useful" (from 46.8% to 54.9%). This improvement appears to be driven by a sharp decline in the "moderately useful" category (from 28.6% to 6.1%), with responses shifting primarily into the higher usefulness levels. Overall, the

post-course rise in the extremely and very useful groups suggests that students increasingly recognize AI chatbots as a valuable learning tool for their studies.

Engagement showed a pronounced increase in the "strongly agree" level. Before the course, only 19.5% of students selected strongly agree, whereas after the course this rose to 56.1%, representing an increase of 36.6 percentage points (56.1 − 19.5). This substantial shift is primarily explained by decreases in agree (from 46.8% to 30.5%) and neutral (from 33.8% to 8.5%), indicating that many students moved toward stronger endorsement after the course. Notably, 4.9% of students reported strongly disagree post-course, suggesting that a small group did not feel engaged. Overall, the sharp rise in engagement reflects a high level of active student participation, despite a minority who remained less engaged.

Taken together, the consistent upward shifts across familiarity, perceived usefulness, and engagement indicate that students completed the course with stronger GenAI-related learning perceptions than they held at the outset, reflecting increased readiness to incorporate GenAI into their learning processes.

Associations Between End-of-Course Perceptions and Use-Related Indicators

This study explored how the students' end-of-course perceptions of GenAI were descriptively associated with two indicators of emerging self-directed GenAI use: intention to continue using AI chatbots for learning and reported frequency of chatbot use during the course. Two descriptive cross-tabulations were used to examine these relationships.

Perceived usefulness and intention to continue using GenAI

Figure 4 shows a very strong intention to continue using the AI chatbot. An overwhelming majority of respondents (92.6%) said Yes, indicating high satisfaction and perceived value. Only a small fraction reported Not sure (6.2%), while an even smaller group (1.2%) said No. Overall, the results suggest broad acceptance and a high likelihood of sustained use of the chatbot AI.

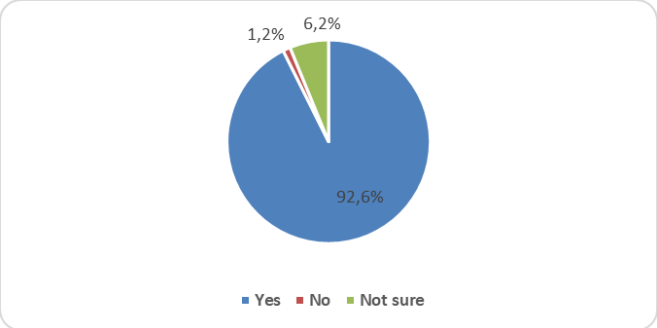


Figure 4. Intention to Continue Using AI Chatbot

As shown in Figure 5, continuation intention is concentrated among students who rated the chatbot at the top end of usefulness. Among those selecting Very useful, 50.6% also reported Yes for continued use, with an additional 3.7% indicating Not sure. A similar pattern appears for Extremely useful: 34.6% reported Yes, while only small shares reported Not sure (2.5%) or No

(1.2%). Students who rated the chatbot as Moderately useful accounted for just 6.2% of the Yes responses, and the lowest usefulness category (Not useful at all) was rare (1.2%).

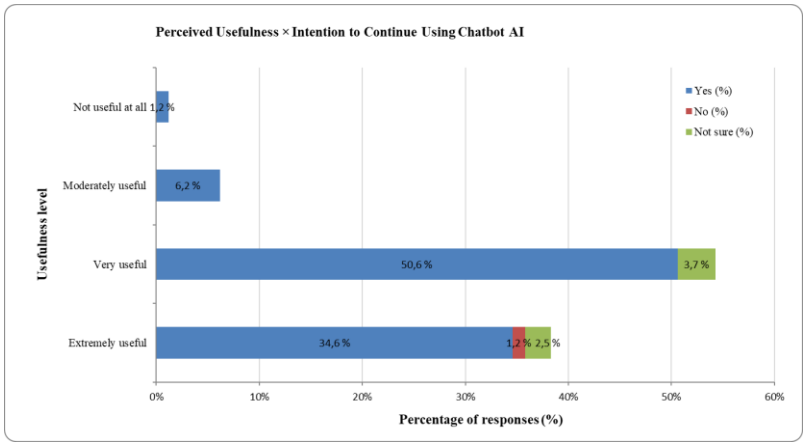


Figure 5. Perceived Usefulness and Intention to Continue Using AI Chatbot

Engagement and frequency of chatbot use

A similar pattern appears when looking at the relationship between perceived engagement and how often students actually used the AI chatbot during the course. As shown in Figure 6, students who reported higher levels of engagement were also more likely to use the chatbot frequently. Among students who strongly agreed that the chatbot improved their engagement, 19.8% reported using it very frequently and an additional 11.1% reported using it frequently. Likewise, within the agree category, a substantial share of students reported regular use, with 35.8% indicating frequent use, 14.8% reporting very frequent use, and 6.2% reporting occasional use.

In contrast, students who reported neutral or negative engagement showed much lower levels of chatbot use. Those selecting neutral were spread evenly across low-frequency categories, with 2.5% each reporting very frequent, frequent, and occasional use. Students who strongly disagreed that the chatbot improved engagement were limited to either very frequent (2.5%) or occasional (2.5%) users, and no sustained pattern of frequent use was observed in this group.

Overall, the distribution suggests a clear descriptive alignment between engagement and use behavior: students who experienced higher engagement with AI-supported activities were more likely to integrate the chatbot into their regular learning practices. This pattern reinforces the idea that engagement plays a key role in translating positive perceptions of GenAI into actual, repeated use during the course.

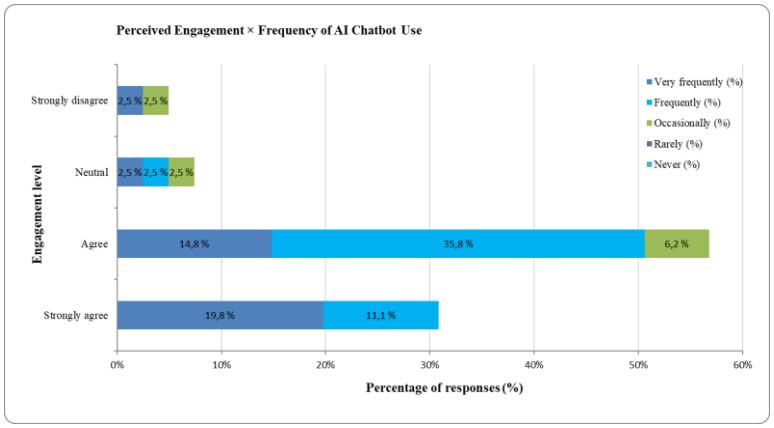


Figure 6. Perceived Engagement and Frequency of AI Chatbot Use

Weekly Perceptions of Effectiveness of GenAI-Supported Activities

A week-by-week view of student responses provides insight into how perceptions of GenAI-supported activities evolved across different course topics rather than at a single endpoint. As shown in Figure 7, students' perceived effectiveness of GenAI-supported activities remained consistently high throughout Weeks 4–10, with mean ratings ranging from 4.34 to 4.77 on a five-point scale. Ratings increased steadily from Week 4 (M = 4.34) to Week 6 (M = 4.58) and remained relatively stable through Week 8 (M = 4.71), suggesting growing comfort and effectiveness as students gained experience using the chatbot within structured activities.

A temporary decline was observed in Week 9 (M = 4.50), followed by a rebound in Week 10 (M = 4.77), the highest mean rating recorded during the course. The dip in Week 9 coincided with the instructional unit on professional ethics, a topic that several students identified as more abstract and challenging to interpret, particularly for first-year learners. The subsequent increase suggests that the lower rating reflected topic difficulty rather than a broader decline in perceived value of the GenAI-supported approach.

Overall, the pattern indicates that students consistently viewed GenAI-supported activities as effective across the semester, with modest fluctuations aligned with course content. These findings highlight the value of longitudinal, week-by-week evaluation in capturing how perceived effectiveness varies with instructional context, rather than relying solely on pre- or post-course measures.

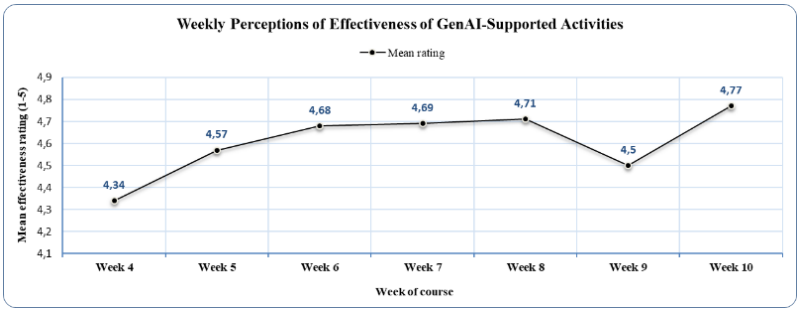


Figure 7. Weekly Perceptions of Effectiveness of GenAI-Supported Activities

Discussion

The findings provide classroom-based evidence that a course-grounded GenAI chatbot can function as a practical scaffold for freshmen's transition toward SDL in a required introductory civil engineering course. Consistent gains in familiarity, perceived usefulness, and engagement suggest that students did not simply "get used to" GenAI. Rather, they increasingly recognized its instructional value when the tool was embedded in structured, discussion-centered activities. This pattern aligns with previous studies showing GenAI can improve learning experiences, but impacts vary substantially by pedagogical design and implementation context, underscoring that effectiveness depends on how the tool is integrated rather than access alone [6], [9], [10], [14].

The descriptive associations between perceived usefulness and intention to continue using GenAI, as well as between engagement and frequency of use, also align with core expectations of technology adoption frameworks (e.g., TAM/TAM2) in educational contexts: positive perceived value is linked to sustained intention, while engagement is closely tied to repeated use behavior [6], [16], [17], [18].

Finally, the week-by-week effectiveness ratings strengthen arguments from recent literature calling for longitudinal evidence on how GenAI use evolves across a semester rather than relying only on one-time or pre/post snapshots. The observed dip during the professional ethics unit suggests that GenAI-supported learning can be topic-sensitive, with more abstract or judgment-oriented content requiring additional instructional mediation. This finding is consistent with broader calls for educators to remain central as "guides" in GenAI-supported SDL and to adjust scaffolding based on task demands and learner readiness [6], [9].

Overall, the findings suggest that a course-grounded GenAI chatbot can strengthen freshmen's SDL when its use is intentionally guided and embedded in structured activities. In construction and civil engineering education, this scaffold is most effective when aligned with authentic tasks (e.g., defining scope, interpreting project lifecycles, and applying professional judgment) and when students must justify assumptions and revise their thinking against course criteria. Used this way, the chatbot supports SDL processes, goal setting, self-monitoring, and self-correction, simultaneously reducing answer-seeking and over-reliance.

Conclusion

This study shows that integrating a course-grounded GenAI chatbot into a required freshman civil engineering course can meaningfully support students' transition toward self-directed learning. Through structured and guided use, students developed greater familiarity, perceived usefulness, and engagement with GenAI, indicating increased readiness to use AI as a learning support rather than a passive shortcut.

Importantly, these perceptions were linked to actual learning behaviors. Students who viewed the chatbot as useful were more likely to intend continued use, while students who reported higher engagement also used the chatbot more frequently. These findings reinforce the relevance of the Technology Acceptance Model and highlight engagement as a critical mechanism that connects positive perceptions to sustained, self-directed use.

The week-by-week analysis further demonstrates that the effectiveness of GenAI is context-dependent, varying across course topics rather than remaining static. This underscores the need for longitudinal evaluation and targeted instructor support, particularly when students engage with more abstract or judgment-based content.

Overall, the findings suggest that GenAI can function as a reliable learning scaffold in large, required freshman engineering courses when it is course-grounded, pedagogically structured, and human-centered. Effective AI integration therefore depends not simply on access to technology, but on intentional instructional design that supports sustainable self-directed learning.

This study has several limitations worth noting. The evidence comes from a single freshman civil engineering course at one institution, thus the findings may not represent broader student populations, other engineering majors, or different instructional settings. The study examined one course-grounded chatbot intervention within a specific ten-week course design, which may limit transferability to courses with different content, pacing, or assessment structures. The analysis is largely descriptive; while the mixed temporal data reveal meaningful changes and clear associations among perceptions and use-related indicators, they do not explain in depth why these shifts occurred or which mechanisms were most influential. Another limitation involves the instructor factor. The chatbot was embedded through a particular facilitation style, including how discussions were structured and how students were encouraged to use the tool. Consequently, the observed outcomes cannot be fully separated from instructor-specific pedagogy, peer dynamics, or other course features. These constraints suggest that results should be interpreted cautiously and validated through multi-course, multi-instructor studies.

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