

GIFTS: Generative AI Chatbots As a Structured Tool for Reflective Writing in First-Year Engineering Introductory Courses

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Introduction

This GIFTS paper shares a class-tested practice for enhancing reflective writing assignments in E102: Engineering in the 21st Century, an introductory engineering course offered at a large public university. E102 introduces students to the 14 Grand Challenges of Engineering developed by the National Academy of Engineering (NAE). The course emphasizes engineering identity development, self-exploration of engineering disciplines, and professional practice. The purpose of this particular course structure is to help students explore and select an engineering major. Mazzaro *et al.* found that students often select a major without a thorough understanding of the connections between the discipline they choose and their interests [1].

Reflective writing enhances critical thinking and helps develop a 21st-century engineering identity [2, 3]. This includes boosting metacognitive awareness and critical thinking with scaffolding for the peer review and revision process [4]. This implementation sought to evaluate if artificial intelligence (AI) scaffolded reflective writing could help first-year engineering students who have not matriculated to tie their personal interest with a specific engineering major.

This implementation utilizes generative AI chatbots, such as OpenAI ChatGPT and Google Gemini, as structured pedagogical tools for scaffolding learning about the Grand Challenges of Engineering and the engineering disciplines offered by the university. The learning outcomes of the course included understanding the skills required to perform various engineering majors and how those skills can be applied to the Grand Challenges of Engineering, as well as identifying between disparate fields of study like social sciences, political sciences, and engineering.

Learning objectives for this assignment were 1) Evaluate AI as an educational and professional tool for engineering development; 2) Analyze the intersections between Engineering Grand Challenges and the students' personal interests outside of class; and 3) Develop deeper major exploration through reflective writing skills.

Motivation for Innovation

Reflective writing in first-year engineering fosters critical thinking and self-assessment by guiding students to evaluate their reactions to course material [5]. When properly structured, these assignments catalyze identity formation as students bridge new technical concepts with existing personal knowledge [6]. Historically, however, E102 lacked a dedicated reflection component, and students struggled to connect abstract engineering challenges to their specific career goals. This reflects a common hurdle where first-year students lack the metacognitive bridge necessary to align emerging technical skills with long-term professional aspirations [6].

To address this gap, this activity was developed to provide structured guidance on utilizing Large Language Models (LLMs) as cognitive scaffolds [7]. Rather than using AI as a content generator, this framework positions LLMs as tools for ideation and structural support, which has been shown to lower the barrier to entry for complex writing tasks [8]. By requiring students to reflect on the AI's contributions, this intervention seeks to mitigate risks of cognitive offloading while fostering the deeper metacognitive awareness required for professional identity development [9, 10].

Implementation

Two hundred and thirty-eight first-year engineering students enrolled in four sections of E102 participated in this study. The participants were assigned in these sections randomly and the researchers had no inference in the process. Participation in the research study was voluntary and responses were de-identified prior to analysis. To maintain anonymity, each student was given a random identifier. Surveys were administered at the start and end of the semester to assess students' perceptions and knowledge regarding educational tools used, as well as their satisfaction with the writing assignment method. This study was reviewed and approved by our university's Institutional Review Board (IRB) (IRB protocol #27134).

The control group (Group A) consisted of 58 students from one of the four sections in the study. The modification group (Group B, n=179) was composed of three of the four sections of E102. Both groups were tasked to complete the same deliverable, which is a 500- to 1,000-word essay to identify the most critical Engineering Grand Challenge, detail why they think this grand challenge is so critical, and connect their interest with the significance of the issue.

The survey design consisted of self-report items to elicit responses that align with engineering identity (interest, competence, recognition, and career alignment) in addition to perceptions of AI-based writing tools (perceived usefulness and confidence). The Qualtrics instrument, delivered via email and class lecture slide invitations, was a mixture of Likert-style questions, checkbox/multiple choice items, and open-ended prompts that required short responses in text boxes. All Likert scale items used a 5-point response scale with 1 being "strongly disagree" and 5 for "strongly agree".

No structured instruction was given to Group A on prompt design, AI-supported idea generation, or editing. Instructions and rubrics to complete the assignment successfully were given to the group but no breakdown process was provided nor final reflection was asked to be completed. Group B received instructional scaffolding for the assignment on prompting and re-prompting, outline generation, and AI-assisted revision. All four sections received guidance on the ethical and effective use of AI-based writing tools like ChatGPT, Google Gemini, and Microsoft CoPilot. The assignment given to Group B was divided into five parts and given over several weeks at the start of a 15-week semester. Students were instructed to use the free version of ChatGPT or the university-supported version of Gemini to complete all steps of the reflective writing assignment.

The five steps of Group B's assignment, including example prompts, are included in the Appendix. The instructor modeled during class instruction time as well as provided a short video on the LMS for personal playback. This reinforces the importance of instructors having a working knowledge of chatbots used in class, including its advantages and limitations, to effectively guide students.

Recent research underscores the risks of cognitive offloading when students use LLMs without prior reflection, letting the AI 'think' for them. To minimize this, pedagogical frameworks now emphasize having students perform intentional pre-AI thinking to maintain intellectual ownership and agency [11]. This framework served as the basis for Step 1 instruction for Group B, requiring students to engage in introspection before interacting with the chatbot.

Assessment

Of the students who took the pre-survey (n=237), fifty eight students were in the control group (Group A) and 179 students were in the modification group (Group B). For the post survey (n=206), forty were in Group A and 148 students were in Group B. Participation was voluntary and was not tied to incentives like extra credit or grade replacement, which may have prompted the attrition in responses from Group B.

This study had several limitations. First, the use of de-identified data prevented matching individual students across pre- and post-surveys. Because of this, any observed changes show group-based differences (Group A vs. Group B) instead of the growth of an individual student. Differences between pre- and post-surveys may also reflect variation because of attrition, given that some students chose not to complete a post-survey. Outcomes measure self-reported perceptions, which may not fully represent a students' actual competence related to AI use or engineering capabilities.

Two metrics were analyzed: 1) The student's perception of the utility of an AI chatbot assisting them in writing (Labeled as "Utility"); and 2) The student's confidence in using a chatbot to assist in writing course documents (Labeled as "Confidence"). The Top-2 label in Table 1 denotes the combination of 'Agree' and 'Strongly Agree' responses.

Table 1. Data analysis results from both groups expressed as Top-2 responses

Group	Stage	Utility % (Top-2)	Confidence % (Top-2)
Control	Pre	40%	47%
	Post	23%	23%
Modification	Pre	34%	35%
	Post	42%	59%

DiD Effect		+25% ($p = 0.033$)	+48% ($p = 0.0005$)
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The Modification group saw an increase in students finding the chatbot useful. The p-value suggests that the results are statistically significant. The structured approach successfully convinced more students in Group B of the value of AI than the traditional ‘hands-off’ approach in the Control.

The DiD (difference in differences) rate shows that scaffolding helped the students feel capable of using the intervention (AI chatbots) to complete the reflective writing assignment. The control group’s drop from 47% to 23% suggests that students may have become less convinced that AI was helpful in completing their writing assignment for the course.

The study does provide insight into how differing levels of instructional scaffolding around AI-supported writing may be associated with students’ confidence in AI tools and the development of engineering identity in an introductory engineering course. By requiring Group B students to reflect on how their AI-generated outlines changed (Step 4), they were being forced to engage self-assessment around the Grand Challenges of Engineering, and with deeper critical thinking and metacognition. Examples of Group B student reflective essays (Step 5) are presented in the Appendix.

Summary

This research suggests a framework for using AI chatbots as a structured writing tool in first-year engineering. The study supports the hypothesis that tools like ChatGPT and Gemini can effectively assist students with reflective writing. While AI use did not significantly strengthen the connection between personal interests and engineering disciplines in this specific trial, students in the scaffolded group (Group B) demonstrated marked improvements in confidence and perceived utility compared to the control group.

The DiD results suggest that instructional scaffolding like modeling prompt design, outline generation, and iterative revision helps students feel capable of using AI as a professional tool. These findings are consistent with prior research, indicating that scaffolding enhances students’ sense of competence in using AI. Ultimately, implementing methods that showcase proper chatbot use while clearly communicating the limitations and risks associated with these tools in academic settings is crucial.

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Appendix

Assignment Steps

1. STEP 1: Crafting The Original Prompt:
 - a. List four of your possible professional (career) interests, in addition to engineering.
 - b. Log into ChatGPT and enter your first prompt combining those interests similar to the example below. Example Prompt 1: What engineering disciplines and careers blend music and construction and also address the National Academy of Engineering's Grand Challenges of Engineering?
2. STEP 2: Expanding on the Prompt:
 - a. Re-open ChatGPT and prepare to build on your original prompt to create a follow-up prompt.
 - b. Example follow-up prompt : Write a bulleted outline for an essay exploring number [fill in the blank, using the specific chatbot response] above.
3. STEP 3: Library Research:
 - a. Students were instructed to use the university library database to search for sources to support their technical assertions in their expanded bulleted outline used as a basis for their essays.
4. STEP 4: Writing the Essay:
 - a. Finally, it's time to start writing the 750- to 1,000-word essay based on your research-based GPT-empowered outline. You're free to revise your outline at this stage. If you do, please explain how it changed.
5. STEP 5: Reflection:
 - a. Write a 200- to 400-word reflection on your experience using ChatGPT as a writing aide during this essay assignment.
 - b. Questions to address: In what ways did generative AI help or hinder your writing process? What new career ideas did you discover?

Themes Observed in Group B's Reflection (STEP 5):

Making connections:

The use of AI had some interesting outcomes from using it. I liked how it helped me brainstorm different careers.

Going into this assignment, I considered Transportation Engineering as a speciality within Civil Engineering. I now see that it is once again a broad field with many different pathways or combinations of pathways that one could pursue, such as within rail, public infrastructure, architecture, layouts, and much more.

I learned about new and exciting fields such as Neurogaming and Brain-Computer Interface (BCI) Engineering, careers that perfectly connect to my interests in technology and creativity.

In the beginning, I wasn't entirely sure how to organize my thoughts or connect the technical aspects of aerospace engineering to the Grand Challenges of Engineering. ChatGPT helped me brainstorm and clarify ideas without actually writing the essay for me. It was like having a tutor who could walk me through examples and explain how to tie my research into larger engineering concepts

Critical thinking:

A lot of the times the AI wasn't super helpful and needed a lot of reprompting until I could finally decide on a direction.

My biggest takeaway was that it's been a while since I needed to write an essay, and I'm rusty. I also really don't like using AI, it slowed me down and confused my writing process.

Generative AI definitely made things easier when it came to brainstorming and structuring ideas, but it also showed me how important it is to stay confident in my own writing ability. It helped me fix grammar and polish my sentences, but the actual ideas and tone still had to come from me.

The outline it provided was somewhat helpful, however I wasn't very sure of what the exact prompt of the assignment was until the writing stage, so I don't feel like the AI outline very accurately matched the assignment, and because of this I struggled to write the requested paper within the prompt.