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Leveraging Student-AI Interaction to Evaluate Competence in Generative AI and Technical Domains in Industrial Engineering

Dr. Nadiye O. Erdil, University of New Haven

Nadiye O. Erdil is an associate professor of Industrial and Systems Engineering and Engineering and Operations Management at the University of New Haven. She teaches at the undergraduate and graduate level and has held various academic positions including administrative appointments. Her expertise spans engineering education, quality and productivity improvement through statistical tools, lean methods and application of information technology in operations management. Her research primarily focuses on manufacturing and healthcare delivery operations. Additionally, she has practical experience as a process engineer in the sheet metal manufacturing and pipe fabrication industry, where she worked for several years. She holds a Ph.D. in Industrial and Systems Engineering and M.S. in Industrial Engineering from Binghamton University (SUNY); and a Bachelor's degree in Computer Engineering from Bogazici University.

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Introduction

This research aims to evaluate the current student generation's proficiency in generative Artificial Intelligence (AI) usage and explores whether student-AI interaction, broadly defined as how students use AI tools to learn and complete tasks, can serve as an instructional tool to assess competence in technical Industrial Engineering (IE) domains. This work-in-progress paper, as part of this research, presents findings from activities implemented in three graduate level IE courses, Design of Experiments, Lean Six Sigma and Quality Analysis, during the Fall 2024 term and addresses lessons learned from challenges encountered.

The Fourth Industrial Revolution, or Industry 4.0, centers on the integration of advanced digital technologies in manufacturing and the service sector. Its goal is to enhance connectivity across the value chain, improving efficiency, quality, sustainability, customer experience and cost reduction. Although Industry 4.0 implementation is progressing rapidly, engineering education, including IE, has lagged in updating curricula to align with these developments. Simultaneously, Industry 5.0 is emerging, emphasizing deeper collaboration between humans and machines, with AI playing a pivotal role beyond automation and data analysis which are the core aspects of Industry 4.0.

Within these transformations, generative AI, a subset of machine learning, has gained significant attention due to its rapid advancement, accessibility, and potential to reshape thinking, learning and problem solving. Generative AI is also at the forefront of discussions in higher education including its potential uses in and beyond the classroom. Initially, the focus was primarily on preventing students from using generative AI tools, but attention is now shifting toward integrating these tools into teaching and learning [1]. Many educators are exploring ways to incorporate generative AI into instruction [2].

Students are often assumed to be tech-savvy [3]. With the widespread use of tools like ChatGPT, they may also be perceived as competent users of generative AI. However, effectively using AI for learning requires more than just basic digital literacy, which can impact both the learning experience and its benefit. Therefore, studying students' interactions with AI is important, as the findings will shape how generative AI tools should be introduced and utilized in education.

This study was built on evaluating these interactions to determine whether today's students are equipped with this proficiency, enabling instructors to integrate generative AI as a tool for knowledge and skills assessment in technical domains.

Initial findings indicate widespread use of generative AI among students but lack of proficiency to utilize it effectively for learning. Future work will compare these findings with results obtained after implementing guided learning templates designed to help students critically evaluate and effectively apply generative AI tools.

The next sections begin with a literature review summarizing the potential of generative AI in education, followed by a description of the study's implementation. The key findings are then presented, highlighting students' interactions with generative AI. The paper concludes with a discussion of the study's takeaways and recommendations for next steps and instructional strategies.

Background

Generative AI holds significant potential to advance education [4, 5]. It can take on various roles in learning including AI-directed (learner-as-recipient), AI-supported (learner-as-collaborator), and AI-empowered (learner-as-leader) [6]. These levels align with categorization of student-AI interactions observed across various disciplines. For instance, [7] classifies these interactions based on dependency: (1) high dependency, where students rely on AI for direct answers and (2) lower dependency, where students use AI to verify their work or gain insights into complex problems. Similarly, [8] identifies three categories based on how students use generative AI and respond to its output: (1) entire response, (2) selective use and (3) reject and retry. As students become more proficient in AI use, they transition from full acceptance, which indicates using the AI-generated response as is, to selective use, where they interpret AI output and integrate it into their learning. Eventually, they develop critical engagement, which involves examining responses, refining queries, and constructing new knowledge. This final stage aligns most closely with the focus of this study.

Research on generative AI and its applications in higher education is steadily increasing, with much of the published work focusing on the use of ChatGPT [9]. From the perspective of students, generative AI offers several benefits. It can assist in developing reading and writing skills by providing suggestions as a writing aid and help automate repetitive tasks and simplify complex ones [9, 10, 11]. Additionally, its potential to deliver personalized learning experiences, enhance student engagement, and improve problem-solving skills by providing explanations and step-by-step solutions is well recognized [9, 12, 13]. Students can also utilize generative AI as a verification and reference tool to refine their work [4,14].

On the instructor side, much attention has been given to how generative AI can support the assessment process [11]. Examples include utilizing ChatGPT to generate quiz questions to support mastery learning [4,12] and providing customized feedback [16, 17]. Other potential benefits for educators include assistance with course planning and development, improved instructional design performance [15], reduction of workload and significant time savings [14].

Despite these advantages, there is a clear need for future research to advance the educational use of generative AI [17]. Specifically, the importance of improving students' ability to effectively utilize generative AI, along with offering guidance to educators on its effective implementation, has been highlighted in several studies [10, 14, 20]. Ensuring that both students and instructors are well-equipped to leverage these tools is essential for realizing their full potential.

The primary goal of this research is to explore the use of generative AI as an instructional tool for assessing knowledge and skills. Effective integration of generative AI in this context requires students to be proficient and comfortable with the tools, especially in academic settings.

Therefore, a key question to address is whether today's students possess this proficiency, enabling instructors to incorporate generative AI for instructional purposes. To investigate this, generative AI usage was adopted in three IE courses, where students were permitted to use AI with acknowledgment but received no specific guidance on how to do so. This approach aimed to assess students' current competency levels and their ability to independently integrate AI into their learning. Proficiency was measured by evaluating the impact of AI usage on assignment scores and the quality of the work.

Implementation

The use of generative AI was introduced in three graduate level IE courses, which were Design of Experiments (DOE), Quality Analysis (QA) and Lean Six Sigma (LSS), during the Fall 2024 term. The following text was added to course syllabi to inform students about the generative AI use policy. "*You are permitted to use AI tools, such as ChatGPT, in this course. Be sure to check the specific submission guidelines for each assignment about the details of permitted use. Keep in mind that AI-generated content can be inaccurate, incomplete, or otherwise unreliable. Additionally, relying too heavily on AI may hinder your independent thinking and creativity. Ultimately, you are responsible for guiding, verifying and shaping the results, and your work should reflect your own understanding. Submitting AI-generated work as your own is not allowed. If you incorporate material produced by an AI tool, you must properly cite it as you would any other source, bearing in mind that its quality may be questionable.*"

Additionally, expectations regarding effective generative AI use and permissible practices in the course were explained in detail during the first class session. Broadly, students were allowed to use generative AI to support all class assignments. For homework, they were permitted to use it to assist in solving problems, provided they disclosed any use of such tools. For project assignments, students could use generative AI to help identify project topics and continue using it throughout the project to generate content for their work. However, they were required to include transcripts of all AI interactions from which they extracted information, suggestions, materials, etc. as part of their project documentation.

Usage data was collected through a simple survey linked to each assignment, asking students whether they used AI programs for assistance. Rubrics were developed to assess proficiency in generative AI usage and competence in technical domains, with the intent of applying them to the required transcripts submitted as part of project reports. An example rubric is provided in the appendix. The evaluation of the technical domain competence focused on whether students' inputs captured key elements of the subject area and demonstrated refinement of AI-generated content by applying core principles and concepts of the technical field to address inaccuracies or omissions. However, as explained in the following section, this assessment could not be completed as planned since only one team submitted the required transcript. This single submission was used as a case example to illustrate rubric application. A revised plan was implemented, involving qualitative assessment through student reflection papers, which were collected after project report submissions.

Findings

Student attitudes towards using generative AI for coursework were evaluated based on data collected from homework assignments. The average generative AI usage across all available instances (n=186) was calculated to be 49.5%, indicating that nearly half of the students used it for homework assistance. The average usage within each domain was: DOE (38.9%, n=90), QA (44.4%, n=36), and LSS (68.3%, n=60). Although all three domains require extensive application of statistical methods, DOE involves more complex and advanced analysis. This may explain the lower usage, suggesting that the level of generative AI usage decreases as the complexity of mathematical analysis, in this case particularly statistical analysis, increases.

Students' consistency in using generative AI was assessed by quantifying instances of steady use. A total of 25% of students used generative AI in all their assignments, while 43.2% used it in more than half of their assignments, indicating a tendency toward regular use of these tools among students.

To evaluate the impact of usage on improvement in learning, two-sample *t*-tests (α=0.05) were conducted to compare the average homework and final exam grades of students who used generative AI with those who did not. The DOE and QA courses had four homework assignments each, while LSS had five. The comparison of homework grades showed no statistically significant difference between the two groups (Table 1). For the final exam grade comparison, students were categorized based on their consistency in using generative AI. Those who used generative AI for more than half of their assignments were placed in the GAI group (n_1=19), while the remaining students formed the no GAI group (n_2=25). This comparison also showed no statistically significant difference (*p-value*=0.055). As discussed earlier and in the following sections, these results may not be entirely unexpected, as the improvement in student learning with generative AI use depends on how well the students utilize these tools.

Table 1 Comparison of generative AI usage impact on students' average homework scores

DOE			**QA**			**LSS**		
p-value	GAI	no GAI	*p-value*	GAI	no GAI	*p-value*	GAI	no GAI
0.669	86.31 n_1=35	87.3 n_2=55	0.416	82.1 n_1=16	85.4 n_2=20	0.064	88.79 n_1=33	92.68 n_2=19

As noted earlier, the generative AI session transcripts were identified as the primary artifact for evaluating competence in both technical domains and generative AI usage. Across all three courses, there were 16 project teams. However, only one team successfully documented their sessions, while the others encountered various issues that prevented proper documentation. These issues included unstructured use of the tool such as ad hoc sessions executed sporadically, lack of knowledge on how to store the sessions and reluctance to seek assistance and neglect of the requirement to document their sessions. Additionally, one team did not use AI at all.

As a workaround, the teams were asked to write and submit a reflection report describing how they utilized generative AI in conducting the course project. Based on the reflection reports from 14 teams, the primary use of generative AI was as a writing aid, primarily for tasks such as paraphrasing, grammar correction, and drafting and organizing content. This aligns with the

earlier findings on lower usage rates in courses with more mathematical analysis as students seem not to be utilizing generative AI for higher level of learning competencies. The second most common use involved seeking interpretations of technical outputs they generated such as ANOVA results, coded coefficients list, and residual plots. Only a few interactions involved purely technical content generation. Examples of such use included asking for experimental design suggestions for a given set of factors and levels, selecting a project topic from a list of alternatives, and refining Failure Mode and Effects Analysis, and House of Quality inputs. The findings on students' utilization of generative AI for learning combined with the issues they encountered in using generative AI to generate content for their learning is an indication that students have a clear need in developing AI proficiency.

ChatGPT was the most frequently used tool, with one team also using Gemini, and a few others mentioning Grammarly and Quillbot. It is important to note that while these latter tools leverage generative AI methods, they are more accurately described as AI-powered writing assistants rather than purely generative AI tools. Lastly, two teams commented that the tool provided incorrect responses when interpreting graphs and that made it no use for their learning of the course material.

Figure 1 shows a word cloud that was generated in ChatGPT. It highlights the common themes in student reflection papers, which emphasizes that the primary use of generative AI among students was to assist with writing tasks.

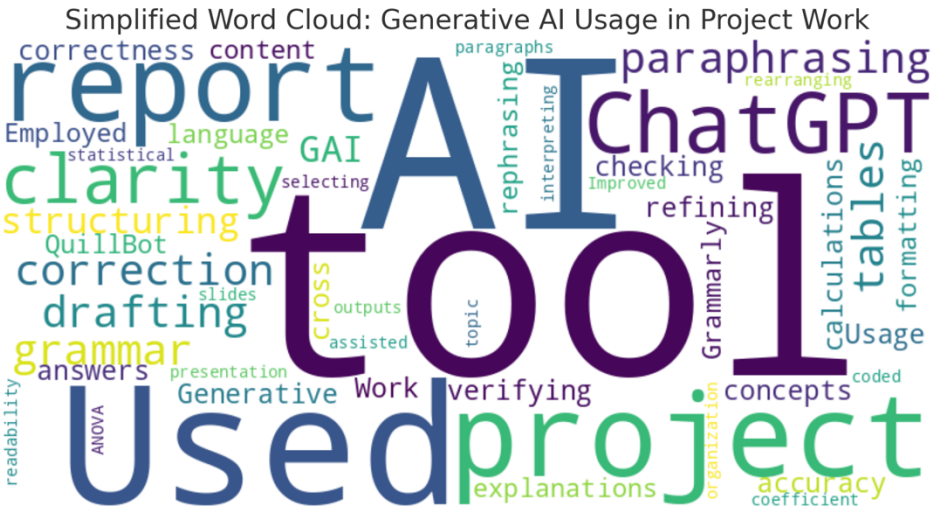

Figure 1 Word cloud by ChatGPT analyzing student reflection responses in context

As noted earlier, only one team utilized generative AI in developing their project topic and executing the work; this team was in the DOE class. They effectively documented their interaction with the tool. This documentation provided an illustrative example of whether student-AI interaction can serve as an instructional tool to assess competency in the technical domain and in using generative AI. The team started by asking generative AI to assist in designing a three factor experiment involving baking. They supplied the project sheet and proposal form as input. Generative AI provided a detailed response capturing an acceptable

experimental design. The team then engaged in iterative discussions refining its initial suggestion to fit their available resources and address key technical concepts. These included selecting appropriate factors, determining the number of levels, scheduling the sequence of runs, and identifying critical considerations specific to their physical experiment. Generative AI was also utilized in developing a data collection and analysis plan, for which its recommendations included "use ANOVA to identify significant factors and interaction, create main effects plots and interactions to visualize the results, develop a regression model to describe the relationship between factors and responses, and use statistical software (e.g. Minitab or R) for analysis".

The rubric, provided in the appendix, was used to assess student proficiency in using generative AI. It was also mapped to the course learning outcomes to evaluate competence in the technical domain, design of experiments in this case. This course has five learning outcomes:

- CLO1. Explain statistical methods fundamental to experimental design;
- CLO2. Design appropriate experimental designs for various scenarios;
- CLO3. Conduct experiments to evaluate performance of an operation, process, or product;
- CLO4. Interpret experimental data to determine best possible solutions; and
- CLO5. Apply design of experiments methods using statistical software.

The rubric covered three of the five CLOs with varying strengths: H (high), M (medium), and L (low). The two course outcomes, CLO3 and CLO5 were not captured as they require physical applications, which was not part of the expected generative AI-student interaction. The abbreviated rubric, its mapping to the course learning outcomes, and the student scores are shown in Table 2.

The team scored 15 on the evaluation, placing them in the "Proficient" band, defined as "The student effectively uses GenAI in most stages, with minor gaps in execution or critical analysis." This score realistically reflected student competence, both in generative AI use and in the technical domain.

Table 2 Evaluation rubric

GenAI usage criteria	**Strength of Relationship**	**Course Learning Outcome**	**Competency Level**
C1. Prompt Crafting for Problem Definition	M	CLO1	4
C2. Prompt Crafting for Experimental Design	L	CLO1	3
	H	CLO2	
C3. Critical Analysis of GenAI's Contributions	M	CLO1	3
	H	CLO2	
	H	CLO4	
C4. Integration of GenAI's Outputs into Experiment	M	CLO4	3
C5. Data Analysis and Insights	H	CLO4	2

Conclusions and Future Work

As discussed earlier, there is a significant emphasis on using generative AI in education, for both as a support tool for instructors such as assisting with tasks such as developing course plans, creating assignments, and evaluating student work, and as a learning aid for students. For the latter, it is essential to ensure that students are well-versed in using these tools, and moreover, are able to utilize them to enhance their learning. The study presented in this work-in-progress paper was conducted to explore this aspect.

Usage analysis reveals that while generative AI adoption is widespread among students, not all students are utilizing it or utilizing it consistently. Furthermore, students use generative AI mostly as a writing aid. The results of the statistical study of on student grades, the findings on students' generative AI usage habits and the challenges they faced in critically engaging with generative AI point to a clear need in developing AI proficiency. Exploiting the broader potential of generative AI as a learning tool, as demonstrated by one team's interaction with it in executing their course project would only be possible by then. Therefore, whether implemented at the program level or in individual courses, a key task for educators is to help students develop proficiency in using generative AI tools. Providing this support within the specific context of the technical domain, rather than focusing solely on general applications, can result in improvements in more than proficiency with the tool. This may create opportunities to strengthen students' competencies in their fields as the students become capable in critically analyzing generative AI's responses using domain knowledge and understanding and effectively incorporating its suggestions into their work. This approach would also allow instructors to use these interactions as a tool for assessing technical domain competence, as illustrated by the case example discussed earlier.

For the three courses included in this study, the next step is to develop generative AI-Assisted Learning Templates and guide students on their use. Further assessment can then evaluate whether students' collaboration with generative AI tools reflects their proficiency in the technical domain and provide further insights into how to best prepare students for the rapidly evolving workplace.

Lastly, it is important to acknowledge the concerns and risks associated with using generative AI, which were a limitation in this study. Some issues were taken into consideration; for example, students were expected to critically examine the responses and refine them based on key principles and concepts of the technical field to eliminate any inaccuracies or oversights. However, other aspects, such as ethical use, bias, and data privacy, were beyond the scope of this paper. These elements should also be addressed as part of student training on generative AI.

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Appendix:

Table A. Rubric* to Evaluate Competency in Generative AI (GenAI) and the Technical Domain (DOE)

Criterion	Advanced (4)	Proficient (3)	Developing (2)	Beginning (1)
C1. Prompt Crafting for Problem Definition	Crafts precise, detailed prompts to help define a meaningful experimental problem, ensuring the problem is aligned with DOE principles. Iteratively refines prompts for clarity.	Prompts effectively help define the experimental problem, with minor need for refinement.	Prompts are vague, leading to a partially defined or unclear experimental problem.	Prompts fail to effectively assist in defining the problem, leading to irrelevant or incoherent results.
C2. Prompt Crafting for Experimental Design	Develops well-structured prompts to explore experimental design options, identifying key factors, levels, and response variables with input from GenAI.	Uses GenAI to develop an experimental design, identifying most key components, but lacks refinement in prompts for specific design details.	Prompts yield a basic or incomplete experimental design, with insufficient details on factors, levels, or variables.	Prompts for experimental design are vague or overly generic, failing to align with DOE principles or course objectives.
C3. Critical Analysis of GenAI's Contributions	Thoroughly evaluates GenAI's suggestions for problem definition, design, or analysis, identifying inaccuracies, biases, or oversights and adjusting accordingly.	Generally, evaluates GenAI's outputs, addressing most inaccuracies or biases, but with occasional gaps in judgment.	Shows limited ability to critique GenAI's outputs, leading to partial or imprecise problem definition, experimental design, or analysis.	Accepts GenAI's outputs without critical evaluation, resulting in significant errors or misalignment with the project objectives.
C4. Integration of GenAI's Outputs into Experiment	Seamlessly incorporates GenAI's suggestions into project components (problem definition, experimental design, analysis) while maintaining originality and coherence.	Effectively integrates GenAI's inputs into the project, with minor lapses in originality or coherence.	Uses GenAI outputs with limited integration or originality, occasionally causing inconsistencies or gaps in the project.	Relies heavily on GenAI outputs without meaningful integration, leading to a disjointed or incoherent project.
C5. Data Analysis and Insights	Leverages GenAI effectively to generate hypotheses, explore analysis methods, and interpret results; critically evaluates AI-generated interpretations for accuracy.	Uses GenAI to support data analysis and result interpretation, with some evaluation of accuracy or appropriateness.	Employs GenAI for basic analysis or interpretations, with limited evaluation or incorrect application of suggestions.	Does not effectively use GenAI for data analysis or interpretation, leading to incomplete or flawed conclusions.

*ChatGPT was utilized as an assistive tool in the development of this rubric to enhance clarity, consistency, and comprehensiveness.

Scoring Guide

- **Advanced (16–20):** The student demonstrates exceptional proficiency in using GenAI across all stages of the DOE project, from defining the problem to drawing conclusions.
- **Proficient (9–15):** The student effectively uses GenAI in most stages, with minor gaps in execution or critical analysis.
- **Developing (6–10):** The student demonstrates partial proficiency, with significant room for improvement in specific areas like prompt crafting or integration.
- **Beginning (1–5):** The student shows minimal ability to effectively use GenAI, requiring substantial improvement in understanding and application.