ŌTAUTAHI CHRISTCHURCH AOTEAROA NEW ZEALAND
35TH AUSTRALASIAN ASSOCIATION FOR ENGINEERING EDUCATION ANNUAL CONFERENCE
8-11 DEC 2024
THE ENGINEER AND THE WORLD

Virtual Teammates: Transforming Engineering Learning through Generative AI Integration

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CONTEXT
The use of generative Artificial Intelligence (GenAI) in education is increasingly central to pedagogical strategies, significantly enhancing personalised learning, student engagement, and administrative efficiency. However, less explored is the use of AI as an active collaborator in student projects, especially in complex, analytical tasks such as those found in engineering education. In engineering, critical analysis and judgment are essential skills, traditionally improved through individual and team coursework under close mentorship by instructors. This study investigates the impacts of integrating AI tools as 'virtual teammates' in engineering tasks to enhance critical skills.

PURPOSE OR GOAL
This study is motivated by the need to adapt engineering education to the evolving technological landscape, particularly through AI integration. It hypothesises that using generative AI as a collaborative tool in student assessments can enhance critical analysis and engineering judgment, offering diverse perspectives and data-driven insights to refine students' analytical and decision-making skills. The goal is to empirically determine whether the presence of AI in a team setting can positively impact student learning and competency development in engineering disciplines.

APPROACH OR METHODOLOGY/METHODS
Three civil engineering subjects, Surveying (year 1), Soil Behaviour (year 2), and Geotechnical Engineering (year 3), were examined. In Surveying, GenAI helped with spatial analysis and discussion of proposed plantation work. For Soil Behaviour, students collaborated with GenAI to draft sections on results, equipment limitations, and error analysis for their lab reports. In Geotechnical Engineering, teams used three GenAI tools to identify additional site investigations, lab tests, and construction sequences for their projects. GenAI outputs, student prompts, and refined report sections were assessed using a rubric capturing 'Critical Analysis and Engineering Judgment.' This study assesses GenAI's educational impact by comparing the performance of students who used it versus those who did not, focusing on engineering skills and team dynamics.

ACTUAL OR ANTICIPATED OUTCOMES
The outcomes of this study suggest that students collaborating with GenAI as a virtual team member may show improvements in content quality and critical evaluation. While the use of GenAI as a teammate appears to support the learning process, further research focusing on student feedback or the broader impact on learning satisfaction is recommended. These results aim to highlight the benefits of integrating GenAI to improve educational practices.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
Integrating GenAI as a virtual team member may enhance students' critical analysis and engineering judgment. Students act as team leaders, refining AI-generated contributions for improved project outcomes. This model highlights AI's educational benefits, like enhanced engagement and analytical performance, and shows how AI can complement traditional learning methods, empowering students in their roles and responsibilities.

KEYWORDS
Generative AI, Assessment Tasks, Virtual Team Member, Critical Analysis

Introduction

Teamwork is increasingly recognised as a vital component for enhancing learning experiences for engineering students and preparing them for real-world challenges. The pedagogical method of modern learning in higher education encourages students' interactions with their peers in cooperative and team-based learning environments. Teamwork offers an opportunity for members to express their reasonings, practice critical thinking and gain more knowledge from their peers, normally inhibited in instructor-led learning settings (Chang & Brickman, 2018; Hassanien, 2006).

However, despite many benefits, students often face challenges with additional work, team meetings, unequally divided work, and non-participating members (Daba et al., 2017). High-performing students argue that they perform reasonably well as individuals in team-assigned tasks, or even better than others. However, they receive the same or unjust marks despite their uneven contributions or less contributing team members dragging the team mark down (LaBeouf et al., 2016). Moreover, with technological advances and increased use of Generative AI, such as ChatGPT, the issues with teamwork in a blended learning environment are more pertinent including trustworthiness in knowledge sharing (Tossell et al., 2024), and academic dishonesty (Playfoot et al., 2024).

Various past studies emphasised the importance and complexity of teamwork in educational contexts. Tseng and Yeh (2013) highlight the critical role of trust and communication in successful online teamwork, suggesting that technological tools alone are insufficient without a solid understanding of team dynamics and individual behaviours. Additionally, Planas-Lladó et al. (2021) explore the effectiveness of self and peer evaluations in providing insights into both team functionality and individual performance, which can significantly affect the quality of the team's output and the overall educational experience. Despite the potential benefits, issues such as free-riding and the difficulty of accurately assessing individual contributions pose significant challenges, underscoring the need for structured team activities and continuous evaluation to ensure that teamwork enriches the educational landscape.

Moreover, Hirsch and McKenna (2008) explored the enhancement of teamwork understanding through reflection in engineering design education. They emphasised the complexity of effective teamwork instruction in large engineering classes, where diverse student backgrounds and varying levels of commitment can impact the learning dynamics. One key challenge highlighted is the allocation of students into balanced teams, where the presence of non-contributing members can detract significantly from the overall team's effectiveness. This often leads to a preference among some students for individual projects and assessments, as these allow them to avoid the uncertainties associated with teamwork and ensure their personal learning outcomes are not compromised by the uneven participation of others.

On the other hand, the integration of generative AI (GenAI) tools in engineering education is reshaping the landscape of curriculum and pedagogical strategies, offering significant enhancements in personalised learning, student engagement, and administrative efficiency (Shum, 2024; Fatahi et al., 2023; Fatahi 2023;). According to Nikolic et al. (2024), while GenAI tools like ChatGPT, Copilot, and others have demonstrated the ability to manage various types of assessments from online quizzes to complex written assignments, their role extends beyond mere assistance in assessments. According to Chan and Hu (2023), students perceive GenAI as a beneficial tool in higher education, enhancing their learning experience through capabilities like personalised feedback and efficient information synthesis.

Much of the discussion surrounding the integration of Generative AI platforms like ChatGPT into university education has centred on their applications in content generation, personal tutoring, instant feedback, and assignment assistance. However, a less explored and intriguing domain is utilising GenAI as a virtual teammate, encompassing all the comparable uncertainties that a human teammate might exhibit. This novel approach allows students the autonomy to select and interact with their virtual teammates as they see fit, leveraging the unique capabilities of a virtual teammate, and explicitly acknowledging their contributions.

This study aims to delve into this aspect, exploring the potential of GenAI to function as an integral part of team dynamics within the university setting. By examining how students collaborate with an AI teammate, this research seeks to uncover the broader implications and benefits of such integrations in enhancing learning experiences and outcomes.

Research Methodology

Piloting Generative AI as A Virtual Teammate

The core concept introduced in this study is Generative AI as a "virtual teammate" to work alongside students on designated tasks. Given the inherent uncertainties with GenAI, it was crucial for students to work closely with an AI platform such as ChatGPT, reviewing and finalising the reports themselves. In this setup, the student acted as the team leader, with ChatGPT serving as a team member. This approach was applied to assessment tasks currently performed individually or in small teams (e.g., two members) to observe how the inclusion of GenAI as a team member might enhance student performance and competency.

A key aspect consistently assessed across different subjects, using a marking rubric, was "Critical Analysis and Engineering Judgment." For Autumn 2024, three Civil Engineering subjects launched this new approach to integrate Generative AI into traditional educational methodologies, in Soil Behaviour, Surveying and Geotechnical Engineering subjects.

Soil Behaviour Subject: In this subject, students were given the option to select ChatGPT3.5 as a virtual teammate to collaborate on preparing critical sections of their laboratory reports, specifically the "Discussion of the Results, Equipment Limitations, and Possible Sources of Error." Throughout the semester, students undertook four hands-on soil laboratory sessions covering Compaction, Soil Classification, Soil Seepage and Permeability, and Direct Shear Tests in the Soil Mechanics Laboratories. These sessions were designed to enhance hands-on skills and were critical for the students' practical understanding of soil mechanics. The laboratory reports required from these sessions included sections like Introduction, Test Procedure, Results, and Discussion, complemented by appendices containing graphs, data sheets, and sample calculations.

In this initiative, students who selected ChatGPT3.5 as a virtual teammate needed to assign a task to this virtual teammate and precisely formulate their prompts, submitting these alongside ChatGPT’s responses in an appendix within their reports. The responsibility lay with the actual student who also acted as the team leader to ensure the accuracy and appropriateness of ChatGPT's contributions before they were integrated into the final report. It should be noted that, aligned with the Faculty of Engineering and IT guidelines, all students could potentially use GenAI for assistive purposes in background research and self-study, but they had to properly reference and acknowledge AI use in their work. Our instructions made it clear that uncredited use of AI-generated content constitutes academic misconduct under the UTS Student Rules.

The overall mark for the laboratory report assessment task accounted for 30% of the total grade in the subject, with the "Critical Analysis and Engineering Judgment" section—relevant to this study—comprising 30% of the laboratory report score. Indeed, the assessment rubric was divided into four components: "Introduction and Laboratory Test Procedure" (20%), "Data Collection and Accuracy of Calculations" (30%), "Presentation and Layout" (20%), and "Critical Analysis and Engineering Judgment" (30%). This research study focuses solely on analysing the data from the latter component of the assessment. Indeed, the mark for the "Critical Analysis and Engineering Judgement" criterion was based on the depth of result interpretation, equipment limitation analysis, and thorough error analysis, focusing on the impact and improvement suggestions. The same marking rubric was uniformly applied to both individual reports and those with AI assistance, with evaluations based solely on the content of the main report. The inclusion of AI-generated content in an appendix aimed to increase transparency and showcase students' thought processes but did not directly affect the assessment outcomes, ensuring fairness across all submissions. The study assessed the educational impact of GenAI by comparing the performance of students who teamed up with the GenAI tool against those who did not and who completed the task individually.

Surveying Subject: Civil engineering students enrolled in the Surveying subject during Autumn 2024 were invited to participate in this pilot project of utilising ChatGPT3.5 as a virtual team member to assist with completing the report related to Geographic Information System (GIS) for spatial analysis. The report required students to use ArcMap software to identify suitable areas for a plantation. Land use and elevation data were provided, and students needed to determine the total area suitable for plantation based on two criteria: (i) the area must be currently classified as cultivation land and (ii) the terrain slope must be less than 30 degrees.

Furthermore, the students were required to discuss how the suitable area was determined, presenting a critical analysis. Only ChatGPT3.5 was permitted for those who chose the option of the team project in which an individual student could team up with GenAI (i.e. forming a team with two members) where the virtual teammate could be tasked with determining the suitable area and preparing the discussion of the results. The marking rubric for this subject comprised a detailed introduction (5%), computational results of grassland area, minimum and maximum elevation of the studied map (40%), critical analysis and engineering judgement for determination of the area suitable for plantation (40%) and the reflection of the task (15%).

Those who adopted GenAI needed to include the inputted prompt and the direct ChatGPT3.5 output as well as to incorporate a revised and verified version to demonstrate their comprehensive understanding of the project as the team leader. Their performances in the "Critical Analysis and Engineering Judgment" as well as their overall performance of this GIS-based assessment task were recorded, analysed and compared with the rest of the students in the same cohort who did not choose Gen AI as a teammate and who worked individually. The same marker was appointed to grade all the submitted reports and was instructed to award the marks based on the face values of the content regardless of the tools and technologies employed.

Geotechnical Engineering Subject: Students enrolled in the Geotechnical Engineering subject during the Autumn session of 2024 were instructed to employ three free GenAI tools (OpenAI ChatGPT3.5, Google Gemini, and Microsoft Copilot) to address specific questions in their design project assessment task, which composed 30% of the overall mark of the subject. The assessment was designed as a team project; two students and the 3rd member was GenAI. Students were asked to engage these AI tools with powerful follow-up questions to refine and enhance the initial responses. They were asked to document their prompts along with the corresponding AI-generated responses. Furthermore, students had to submit a reflective report (not exceeding one page) evaluating the AI teammate's contribution and verify it against their own answers based on the materials taught in this subject and on other reliable sources. Qualitative analysis was conducted on this subject to assess the effectiveness of engaging with Gen AI. The summary of instructions for students to complete the task is shown in Figure 1.

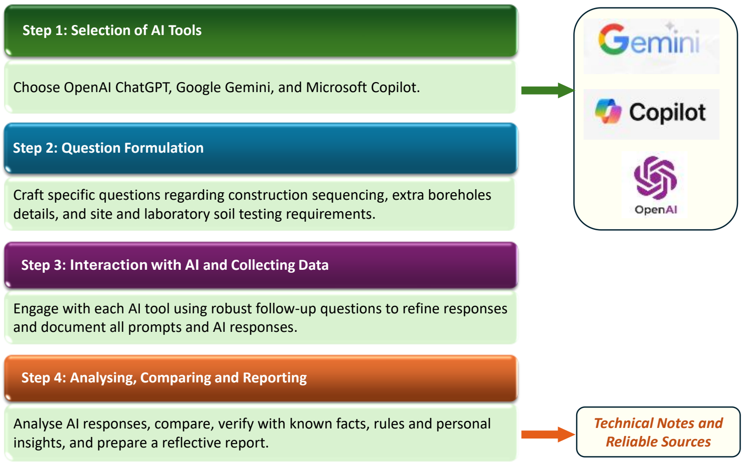


Figure 1: Summary of instructions for students on using Gen AI in their design project assessment task as a teammate in Geotechnical Engineering subject

Results and Discussion

Harnessing Generative AI to Enhance Critical Analysis and Judgment

The cohorts in the Soil Behaviour and Surveying subjects comprised 129 and 210 students, respectively, with the use of ChatGPT 3.5 as an optional virtual teammate. The results from this innovative educational approach revealed significant differences in performance based on the method of task completion.

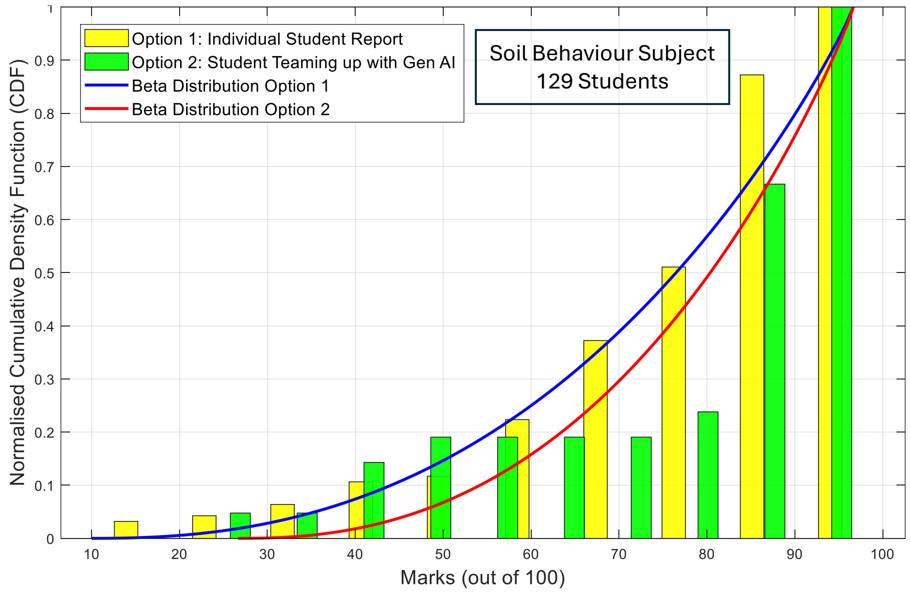
Referring to Table 1 and Figure 2, students in the Soil Behaviour subject who chose to collaborate with ChatGPT (approximately 20% of the cohort), scored a mean of 79% (Distinction Grade) in the "Critical Analysis and Engineering Judgment" component of the assessment of their laboratory reports. In contrast, students who opted to complete the project individually (approximately 80% of the cohort) achieved a mean mark of 72% (Credit Grade). Similarly, results for the Surveying subject reported in Table 1 show that the mean mark was slightly higher for students who had GenAI as a virtual team member (i.e. mean = 86%) as compared to students who did not have a virtual team member (mean = 82%) for “Critical Analysis and Engineering Judgment" assessment criterion. The observed disparities underscore the constructive role that engaging with GenAI as a teammate can play in enhancing educational outcomes, particularly in developing critical evaluation skills and improving content quality.

Table 1: Statistical measures for students’ marks for their abilities for Critical Analysis and Engineering Judgment in Soil Behaviour and Surveying Subjects

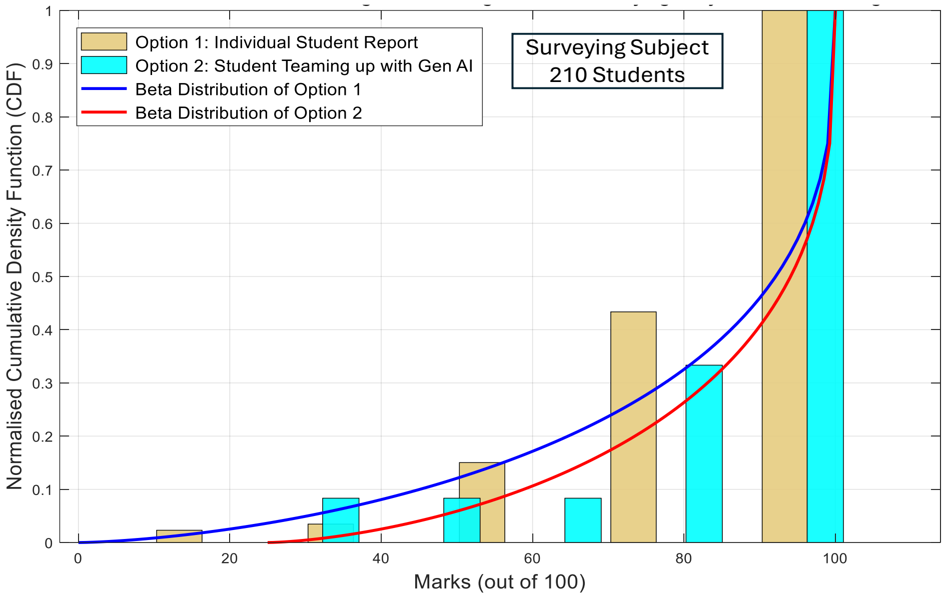
Subject	Assessment Task Option	Mean (/100)	Standard Deviation	Coefficient of Variation	Skewness
Soil Behaviour (129 students)	Option 1 – Individual Laboratory Report	72	18.9	0.261	-1.43
	Option 2 - Student Teaming Up with GenAI	79	20.9	0.265	-1.54
Surveying (210 students)	Option 1 – Individual Student Report	82	22.9	0.280	-1.34
	Option 2 - Student Teaming Up with GenAI	86	22.3	0.258	-2.17

However, not all engagements with ChatGPT were equally successful. The results reported in Figure 2 indicate that the distribution of student scores for this component of the assessment was left-skewed, demonstrating that most students scored above the average, with a significant number achieving higher grades. The longer tail on the left side of the distribution reflects that fewer students scored below average, but those who did had notably lower scores. This pattern highlights a concentration of scores towards the higher end of the grading scale, with only a small number of outliers influencing the average downwards due to their lower performance. Moreover, when students teamed up with GenAI (Option 2), skewness was slightly more left-skewed than Individual Reports (Option 1). This indicates that for Option 2, there are relatively fewer students scoring below average, and the lower scores are further away from the average than those in Option 1.

Looking at the overall performance of students in these selected assessment tasks in both subjects, a similar observation was made. This suggests that teaming up with a virtual GenAI teammate exposes students to an encouraging environment to further explore influential factors pertaining to the topic and to improve their critical thinking and awareness. Discussions with the virtual teammate enable students to make informed decisions with readily available information and higher confidence. Students often require timely support and assistance and having a virtual AI teammate with great potential enables students to engage in brainstorming and stay connected to learn the content. The ability to discuss information and options with a virtual teammate anytime and anywhere can motivate students to critically evaluate the content and complete the required report. In contrast, limited access to instructors or teammates discourages students from performing to the best of their abilities.



(a)



(b)

Figure 2: Beta Distribution of the students marks for their abilities Critical Analysis and Engineering Judgment in (a)Soil Behaviour subject laboratory report and (b) Surveying Subject spatial analysis report

Observations of the study highlight that when students engage with GenAI as part of a collaborative team, they actively practice and enhance their critical thinking skills. This observation aligns with constructivist learning theories (Fosnot, 2005; Al-Huneidi and Schreurs 2013), which suggest that knowledge is actively constructed through interaction and collaboration, not passively absorbed. By treating GenAI as a teammate, students are prompted to refine their inquiries, articulate their thoughts more clearly, and critically evaluate the information provided by AI, transforming passive learning into an active, inquiry-based process.

However, the efficacy of such integrations hinges on students being mentally prepared to accept that GenAI, much like a human team member, may sometimes be reliable and other times not, depending on the level and extent of interaction. It is crucial that students do not view GenAI as an infallible reference or benchmark but rather as a team member whose contributions need to be critically evaluated within the context of their uncertainties. Educators must, therefore, focus on developing strategies to enhance AI literacy and ensure students are equipped to handle these uncertainties by leveraging GenAI effectively. This includes training students not only on the technical use of AI but also on the critical thinking skills necessary to question and contextualise AI responses, treating GenAI as a collaborator whose input is one of many resources available, rather than the definitive source for verification.

Qualitative Analysis of Generative AI Tools in Student Projects

In the Geotechnical Engineering subject, 120 students had the opportunity to utilise various GenAI tools; the majority of students reported that GenAI tools are beneficial for their design projects. Some students encountered incomplete responses, while few either did not employ the tools properly or failed to complete this section of their design project assessment task.

In their reflective reports, some teams noted that the responses from these GenAI tools were clear and highly detailed when queried on specific topics. In addition, some students analysed the responses and compared the performance of three generative AI models (Gemini, Copilot, and ChatGPT 3.5) in addressing geotechnical engineering questions. They noted that both Gemini and Copilot delivered detailed responses and included external online resources to support their answers, while ChatGPT3.5 did not provide suitable references.

In terms of response speed, Gemini and ChatGPT were prompt, whereas MS-Copilot was slower and sometimes caused crashes for some students. Based on criteria such as detail of responses, inclusion of external references, and response speed, many students favoured Google Gemini as an efficient model for this task.

Furthermore, many students emphasised that, while these AI tools can answer a broad range of geotechnical engineering questions, reliance on them should be restrained. Blind trust in the AI might lead to unchallenged acceptance of errors observed in the responses. Hence, a robust understanding of the principles is essential. The students recognised that:

1. Users need a general knowledge of the subject to pose relevant questions and interpret the crucial parts of the responses correctly.
2. All three GenAI platforms (i.e. Gemini, Copilot, and ChatGPT 3.5) explicitly stated at the end of their responses that their recommendations should be verified by an experienced civil engineer to ensure accuracy.
3. Generative AI is a powerful tool for enhancing an engineer's efficiency and productivity, but users must have foundational knowledge to verify the accuracy and applicability of the answers to their specific problems and prevent errors.

Future Opportunities and Recommendations

Looking ahead, the potential to harness more advanced versions of Generative AI in educational settings is immense. For example, the current study utilised ChatGPT3.5; however, future research should explore the capabilities of newer iterations like ChatGPT 4.0 or higher, which promise enhanced analytical and generative abilities that could further transform student interaction with AI.

Moreover, while in this study Gen AI was allowed for a particular section of a specific assessment task, expanding the use of Generative AI across various segments of subjects as students find suitable, could provide a more comprehensive understanding of its impact across different types of learning activities and assessments. This broader application will allow educators and researchers to better gauge the transformative potential of AI in education and its effectiveness in fostering critical thinking and problem-solving skills among students.

Additionally, the initial challenges noted with first-year students struggling to generate meaningful prompts highlight an essential area for development. Providing students, especially those in the early stages of their academic careers, with training on how to effectively interact with GenAI tools could greatly enhance the outcomes of such integrations. Instruction on crafting high-quality prompts and questions can lead to more precise and useful responses from AI, making the interaction more beneficial.

Moreover, future research should explore how different levels of instructor mentorship affect the performance of students teaming up with GenAI. Identifying the optimal level of instructor involvement could enhance the educational benefits of AI integration in team projects, improving student outcomes.

Summary and Conclusions

In the era of readily accessible Generative AI, there has been a significant push within higher education to re-evaluate university assessment tasks, pinpointing those particularly vulnerable to AI influences. Many institutions have embarked on this crucial journey, identifying and redesigning assessment strategies that may be compromised by AI technologies. However, beyond merely identifying vulnerabilities, there is a pressing need to develop new, fit-for-purpose assessment tasks. This research proposes an innovative approach by treating GenAI as a teammate in assessment tasks, mirroring real-world engineering practices where professionals collaborate with colleagues or even AI on projects. This method not only allows students to practice and hone their teamwork skills but also introduces them to the potential uncertainties and misconceptions inherent in working with AI, much like the complexities faced in actual workplace dynamics.

In Autumn 2024, Generative AI was introduced as an optional "virtual teammate" in three Civil Engineering subjects: Surveying (Year 1), Soil Behaviour (Year 2), and Geotechnical Engineering (Year 3), to assess its impact on student performance and critical analysis skills. Students acted as team leaders, actively engaging with and closely reviewing contributions from the GenAI teammate. This educational strategy was evaluated by comparing performance of students who collaborated with the GenAI as a teammate (Option 2) with a control team, where students worked individually or in small teams without the GenAI teammate (Option 1).

Statistical measures of student marks for the assessment criteria revealed that students engaging with GenAI teammates (Option 2), such as ChatGPT3.5, exhibit better performance in areas crucial for their professional development, like critical analysis and engineering judgment. The interaction with GenAI not only supports students in achieving higher academic outcomes but also plays a pivotal role in developing their critical evaluation skills. The positive skew in performance metrics suggests that students are more effectively understanding and applying complex concepts when they collaborate with AI as a teammate. Essentially, GenAI acts as a dynamic learning partner, enabling students to explore deeper insights and refine their analytical skills through active dialogue and feedback. This model of learning fosters a richer, more interactive educational environment where students are motivated to engage critically with the content, enhancing both their learning process and overall academic performance. A further insight concerns teamwork. Students realised that they needed to instruct their AI teammate carefully, using good prompts, if they were to get good output. This realisation could equally be applied to their real teammates, i.e., that team members need clear and complete instructions if they are to produce good work that contributes to the overall team effort. This insight will be further explored in subsequent experiments.

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Acknowledgements

The authors sincerely thank the students of the Autumn 2024 Soil Behaviour, Surveying and Geotechnical Engineering subjects at UTS for their participation in the pilot study. We also acknowledge the use of 'OpenAI. (2024). ChatGPT (Feb-March) [Large language model]' in the process of editing, proofreading & conducting exercises for identifying ChatGPT's abilities and limitations for our pilot study.

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