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Improving Engineering Students' Writing Skills Through a Text Visualization Tool

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Work in Progress: Improving Engineering Students' Writing Skills Through a Text Visualization Tool

Introduction

Due to the importance of communication skills in the professional engineering field, engineering courses have incorporated writing and communication into their curricula [1]. Writing is a multifaceted process requiring critical thinking [2], creativity [3], and synthesis of ideas [4]. For engineers in research careers, writing activates the cognitive and social processes, allowing students aiming for various engineering roles to contribute to their field's broader conversation [5]. Undergraduate engineering students who wrote voluntary reflective journal entry essays on assigned readings performed better on multiple-choice quizzes about the readings than those who did not [6]. Writing tasks serve not only as a means of expression but also as a vehicle for learning and broader intellectual exploration.

In the meantime, the advent of generative AI (artificial intelligence) tools has transformed writing practices in both K-12 and higher education. Generative AI is transforming K-12 and higher education by enhancing students' writing skills. In K-12, it provides real-time assistance by improving grammar, syntax, and style, enabling students to complete assignments such as essays, summaries, and explanations more effectively. Additionally, it generates prompts and ideas, reducing the effort required for creative tasks and making writing less intimidating.

In higher education, generative AI synthesizes information from diverse sources, creating coherent summaries to support research and academic writing. It aids in drafting essays and papers, offering suggestions to improve quality, particularly benefiting non-native English speakers by overcoming language barriers.

Despite its advantages, over-reliance on generative AI poses risks to academic integrity and independent writing skills. Dependence on AI can hinder the development of nuanced language proficiency, rhetorical strategies, and authentic expression. This study explores alternative approaches to using AI as a writing support tool while addressing these challenges responsibly.

If students rely solely on AI-generated content, they forego the process of research, analysis, and synthesis that is integral to deep learning [7]. Relying on generative AI for writing tasks can hinder students' development of essential skills, compromise academic integrity, and diminish the authenticity of their work. While AI-generated text is coherent, it lacks the individuality and originality that define genuine writing. Overuse of AI raises concerns about plagiarism and undermines the value of assessments, threatening intellectual honesty and the credibility of achievements. Writing fosters critical thinking, curiosity, and independent learning, helping students engage deeply with course material and complex concepts. In the AI era, excessive dependence on such tools risks eroding these vital educational opportunities and diluting the integrity of the learning process.

The Need for Writing Support Tools

Incorporating writing support tools, such as guides and scaffolds, is essential in the era of generative AI to address diverse student needs and preferences. These tools, including grammar checkers, proofreading software, outlining aids, and mind-mapping platforms, offer personalized assistance in grammar, syntax, organization, and vocabulary. They help students refine mechanics, structure ideas, and create coherent compositions. Engineering students, in particular, benefit from tools that address complex sentence structures and improve clarity and precision in technical writing.

While these tools enhance inclusivity and accessibility, there is limited research on integrating AI effectively into engineering education. Pedagogical approaches must balance traditional methods with AI innovations to optimize learning outcomes.

Project Approach

The primary objective of this study is to scaffold engineering students' knowledge monitoring process through a knowledge visualization supporting system. We developed and implemented the Knowledge Visualization Intelligence System (KVIS). KVIS uses *spaCy* for information extraction, identifying entities and relationships in student writing. It employs co-occurrence analysis to detect thematic concepts, creating an $n \times n$ matrix of keyword relationships. KVIS visualizes networks and sentence-level domain mapping, illustrating structural relationships and the developmental process in writing. We seek to elucidate the potentials and challenges of the knowledge visualization tool with the overarching goal of promoting engineering students' writing performance.

As an exploratory and preliminary study, this research aims to investigate writing performance when supported by machine learning-based text analytics for knowledge visualization, guided by the following research question: *How do undergraduate engineering students' writing performance change while using machine learning-based text analytics for knowledge visualization?*

This research employed an exploratory study design [8] within a regular course setting. No experimental treatment was applied in the research.

Context and Participants

Participants were recruited from two sections of an engineering technology course offered at a public university in the southern United States. The course focused on computer networking for engineers, and both sections were taught by the same instructor. Experiential learning activities, including problem-solving tasks, group projects, and discussions that required experience and reflection [9], were adopted into the course.

Procedure

Participants reviewed course materials, including content areas and subtopics, to prepare for writing a selected topic essay (a summary of the topic). The topic selection was coordinated with researchers and the course instructor. During the writing process, students used KVIS, which provided real-time knowledge visualization of their work (see Figure 1). This essay-writing activity was conducted six times throughout the semester, with writing performance measured each time. Participation in the writing tasks determined students' scores; full credit was granted upon submission. As a result, students' writing performance did not impact their final course grades.

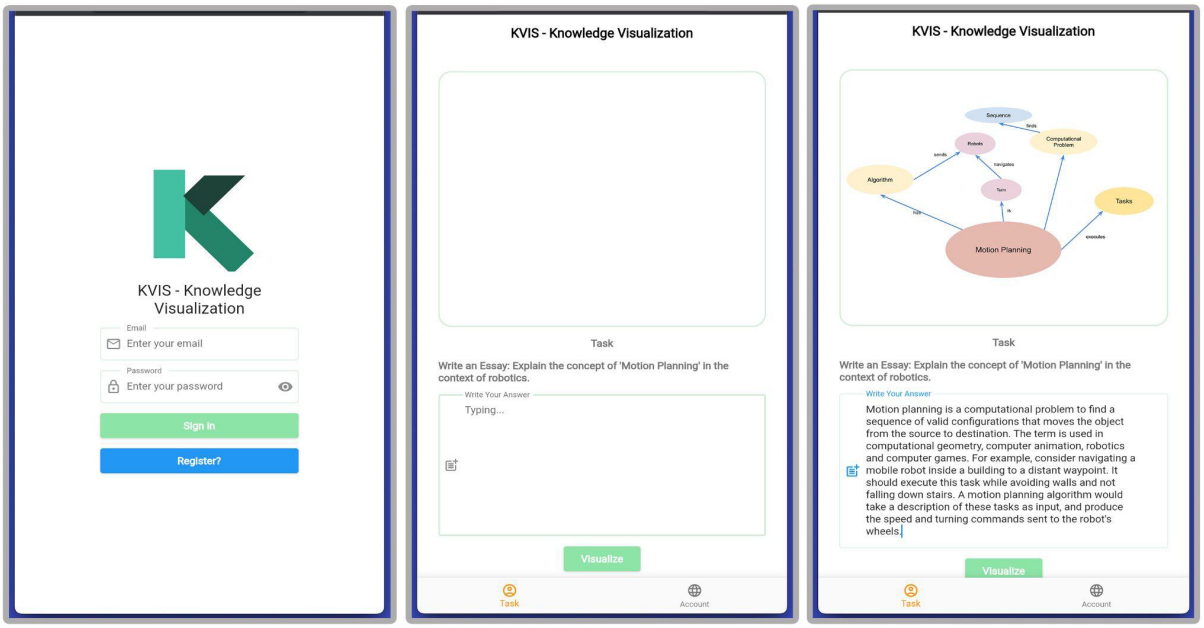

Figure 1. Screenshots of Knowledge Visualization Intelligent System (KVIS): Sign-in (Left), A Writing Task (Center), Visualization and Feedback (Right)

Data Collection and Analysis

For measuring students' writing performance, we adopted the systematically designed information processing rubric with validity and reliability checks [10], which is based on Fischer, Bruhn, Gräsel and Mandl [11]'s framework. For example, the Evaluating category is measured on a scale from 1 (Minimally determined the significance or relevance of information needed for the writing task) to 5 (Completely determined the significance or relevance of information needed for the writing task). When scoring student work in this category, students receive high scores if they identify and articulate the most relevant and significant information for their argument. For instance, when discussing a principle of network security, one student correctly highlighted the most relevant and significant aspect: "… confidentiality can be achieved through encryption, access controls, and other security measures that prevent unauthorized individuals from accessing sensitive information. …"

A one-way repeated measure ANOVA (Analysis of Variance) was conducted to examine changes in writing performance over time.

Results and Discussion

As shown in Table 1, the participants' writing performance changed over the semester.

Table 1. Writing Performance: Mean and Standard Deviation

	T1	T2	T3	T4	T5	T6
Evaluating	4.07 (.75)	4.03 (.62)	4.00 (.62)	4.17 (.62)	4.23 (.34)	4.47 (.41)
Interpreting	4.08 (.79)	3.78 (.74)	3.97 (.66)	3.95 (.63)	3.97 (.49)	4.33 (.46)
Extent	3.15 (.73)	3.77 (.73)	3.80 (.68)	3.80 (.55)	4.11 (.55)	4.15 (.53)
Accuracy	3.71 (.86)	3.55 (.81)	3.72 (.70)	3.73 (.57)	3.87 (.54)	4.12 (.52)
Total	15.02 (2.84)	15.13 (2.71)	15.48 (2.46)	15.65 (2.18)	16.18 (1.74)	17.07 (1.78)

Additionally, using an ANOVA with repeated measures with a Greenhouse-Geisser correction, the mean scores for writing performance over the semester were statistically significantly different, $F(4.082, 118.364) = 5.243$, $p < .001$, with an effect size (*partial eta squared*) of .153. Therefore, to answer the research question, "How do undergraduate engineering students' writing performance change while using machine learning-based text analytics for knowledge visualization?," in this study, throughout the semester, engineering students' writing performance changed over time.

Discussion

This study examines the challenges engineering students face in writing tasks within the context of the generative AI era. The preliminary feedback from students highlights the usefulness of the tool, specifically noting that they did not have the opportunity to simply copy and paste what an AI tool suggests. Instead, they had a chance to rethink and revise their writing through the KVIS tool. In addition, the visualized graph appears to help students capture the overall focus of their writing, rather than losing sight of their main idea by concentrating too narrowly on a specific aspect.

As AI technologies grow more advanced, concerns about over-reliance, ethical use, and misuse have become increasingly significant. Addressing issues such as authenticity, feedback quality, bias, and digital literacy is critical to harnessing the potential of generative AI in engineering education and ensuring equitable learning opportunities. The study investigates how text

analytics-based knowledge visualization can support engineering students' writing performance by focusing on enhancing their self-monitoring processes during writing tasks.

We acknowledge that this study is exploratory rather than experimental, and we cannot argue that the knowledge visualization support tool caused the improvement in writing performance. However, as the instructor specifically prohibited participants' use of generative AI tools in their writing tasks, the results of the improvements could be promising for future experimental studies.

In engineering, proficiency in written communication is highly valued, and engineering students should progressively master skills like written communication, teamwork, and design throughout their undergraduate studies [12]. Although institutional approaches, such as a writing center program, could offer a way to incorporate writing instruction into the engineering curriculum without compromising the emphasis on technical subjects [13], it can be costly. As an efficient and affordable approach, the use of writing support tools would be needed to improve engineering students' writing performance. Generative AI tools might be seen as shortcuts in various engineering courses, but foundational skills in writing must still be taught, helping students define their audience and build arguments before using generative AI for editing [5].

This study explored engineering students' writing tasks and performance, amidst the rise of generative AI, including over-reliance, ethical concerns, and misuse. Key issues like authenticity, feedback quality, bias, and digital literacy must be addressed to fully utilize AI's potential in education and ensure equitable learning opportunities. By leveraging text analytics-based knowledge visualization, the study aims to support students' writing performance, emphasizing the importance of self-monitoring to enhance their skills and maintain integrity in academic writing within the AI-driven landscape.

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