Enhancing Work Efficiency and Learning Effectiveness with Generative AI Chatbots in Civil Engineering

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Abstract

In the civil engineering and construction industry, generative AI chatbots can significantly streamline tasks such as report creation and safety activities. However, relying on AI may reduce opportunities for human learning and skill development. This paper proposes an evaluation method to balance AI-driven efficiency with human capability growth. We developed three chatbots to support reporting, safety activities, and root cause analysis, and present a framework to measure both productivity and learning outcomes through user logs and workplace performance. Our findings suggest that properly designed AI-assisted tools can enhance efficiency and simultaneously foster skill improvement.

Introduction and Background

As the application of AI in the construction industry continues to expand, numerous systematic reviews emphasize its potential in enhancing safety and health management (Mohapatra, Mohammed, and Panda 2023). Beyond efficiency gains, recent work also underscores how human-AI co-creation can foster workers' skill development and organizational learning (Raisch and Krakowski 2021). In civil engineering and construction, daily tasks often combine physically intensive activities, such as operating heavy machinery, with intellectually demanding work, such as writing incident reports and analyzing accidents. Recent advances in generative AI chatbots, supported by large language models (LLM), offer the potential to automate parts of these tasks. Although this automation increases efficiency, there is concern that workers may lose opportunities to learn and develop their skills through direct practice. Consequently, a challenge arises in balancing "efficiency" and "learning facilitation."

The industry also faces routine safety meetings where risks must be identified in a limited time, often leading to omissions. In addition, accident investigations require specialized expertise, which is not always available due to a shortage of trained personnel. Although AI-based assistance can help address such bottlenecks, educational engineering perspectives acknowledge that a heavy reliance on AI carries the risk of influencing workers' independent thinking. Hence, systems must be designed to integrate AI support while still providing learning opportunities, ensuring both productivity gains and human development.

Chatbots Overview

We have developed three chatbots to address industry-specific challenges while also reinforcing worker learning (Table 1). The *Report Generation Support Bot* transforms a handful of user-provided keywords into a draft report, then prompts users to revise and refine the text. This process streamlines routine reporting while giving opportunities to practice writing and organizational skills.

The *Safety Activity Support Bot* quickly proposes various risk items, drawing on past cases and general knowledge to trigger broader discussions in daily safety meetings. By suggesting diverse perspectives, it aims to reduce meeting time while encouraging workers to develop sharper risk detection abilities.

The third chatbot, the *Root Cause Analysis Support Bot* offers a systematic 'why' approach to investigate incidents. Even in environments lacking expert oversight, this bot supports deeper inquiries and hypothesis generation, thus enhancing logical thinking. Figure 1 shows the detailed output for each of the report, safety action items, and cause analysis from a brief input to these chatbots.

Evaluation Methodology

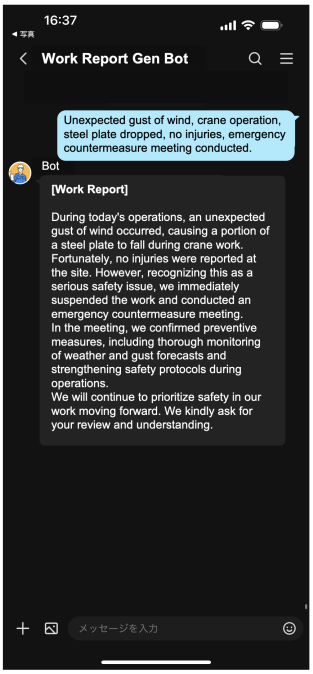
Each chatbot is evaluated through: **(1) Work Efficiency**, examining metrics such as draft creation time, number of identified risks, and depth of accident analysis; **(2) Learning Effect**, observing how users refine AI-generated outputs, develop risk perception, and formulate logical conclusions; and **(3) Co-Creation**, assessing how effectively AI contributions merge with human expertise to yield better final outcomes.

We will gather data from chatbot usage logs, produced reports, and safety meeting records. Comparisons will be made before and after the deployment of these chatbots to measure improvements or potential drawbacks in skill development. Qualitative insights from surveys and interviews will be incorporated to understand worker perceptions and learning experiences.

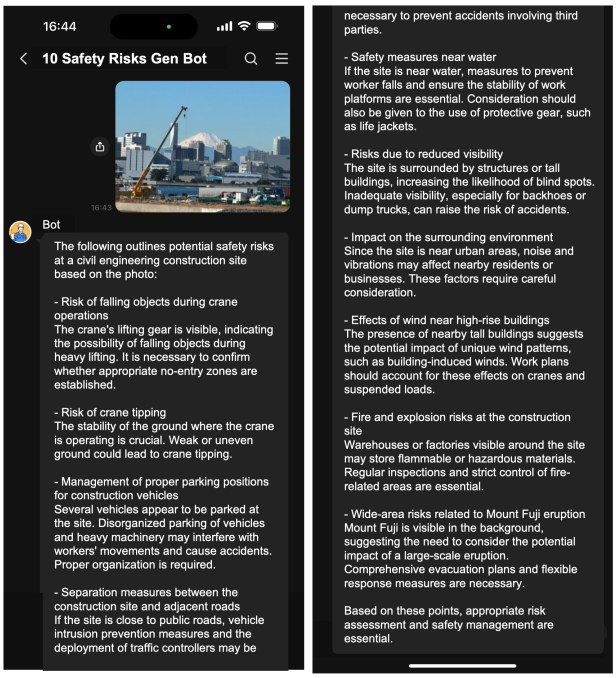
Chatbot	Implementation Purpose	Efficiency Objective	Education Objective	Evaluation Metrics
Report Generation Support	Transform keywords into a cohesive draft	Reduce time for daily/incident reports	Improve writing skills via structured drafting	**Efficiency**: draft time, error rate; **Learning**: edit frequency/depth, structural improvement, self-assessed skill
Safety Activity Support	Propose diverse risks; foster open-ended discussion	Shorten meetings, broaden risk coverage	Develop risk detection skills, encourage participation	**Efficiency**: meeting duration, variety of risks; **Learning**: discussion participation, novelty of perspectives, hazard detection improvement
Root Cause Analysis Support	Guide users with "why" approach, deepen analysis	Reduce investigation time, ensure thoroughness	Enhance logical thinking and hypothesis-building	**Efficiency**: analysis duration, completeness of solutions; **Learning**: logical flow, quality of hypotheses, structured inquiry growth

Table 1: Three chatbots with purpose, objectives, and evaluation metrics

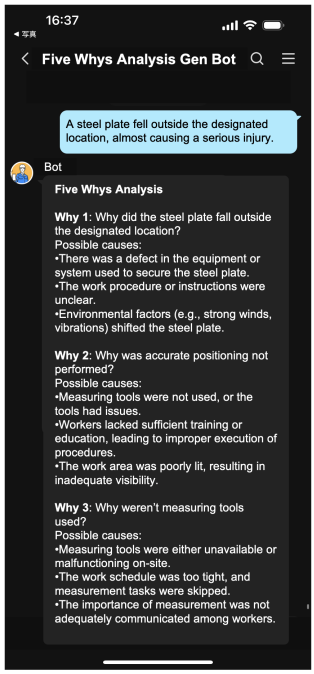
Ex. 1: A work report from a few keywords



Ex. 2: Generating a risk assessment from an image



Ex. 3: Generating multi-layered causes from problem behavior



* Original text in Japanese, translated into English.

Figure 1: Demonstration of the three chatbots in use

Discussion and Future Work

To study the balance between efficiency and learning, a pilot deployment is planned at various construction sites. By refining our evaluation framework, we aim to identify best practices for designing AI systems that reinforce human competencies rather than diminishing them.

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References

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