PAIRING GENERATIVE AI AND SERVICE-LEARNING TO DEVELOP 21ST CENTURY COMPETENCIES IN GEN Z STUDENTS

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The integration of artificial intelligence (AI) skills into education is increasingly important. In Singapore, the Ministry of Education's "Transforming Education through Technology" Masterplan 2030 emphasises developing students' 21st century competencies (21CC). This action research project explored combining the "Problem, AI, Interaction, Reflection" (PAIR) framework with service-learning (S-L) pedagogy to teach AI skills. The PAIR framework, developed by King's College London, guides students in using generative AI tools. The project aimed to enhance AI literacy, critical thinking, and ethics among post-secondary students.

The project was implemented in a module for all Year 1 engineering diploma students from Ngee Ann Polytechnic (NP), Singapore, covering topics including risk management, recognized by Singapore's Workplace Safety and Health Council as bizSAFE Level 2 (bSL2). Using S-L pedagogy, students applied bSL2 skills to serve community stakeholders. They planned engagement activities, assessed risks, implemented a risk management plan, and delivered the project. The PAIR framework was integrated at key milestones: problem formulation, AI tool selection, interaction, and reflection.

In the problem formulation stage, students identified missing information for their S-L project. During AI tool selection, they compared outputs from two generative AI tools and chose the more useful one. In the interaction stage, they used the selected AI tool to plan activities with safety considerations. After project delivery, the reflection stage involved comparing the actual implementation with the AI-planned version to evaluate strengths and weaknesses. A survey with 794 students revealed that 86% felt they learned to critically review AI outputs and became more aware of AI limitations. However, only 76% attributed their critical thinking skills development to the AI tool, while 10% did not find PAIR alone sufficient for this skill development. The results also highlighted that while 75% of students were concerned with plagiarism when using Gen AI tools, only 57% of them were bothered by privacy and security matters. This may potentially heighten their exposure to online risks and is an area worth exploring.

Keywords: *AI literacy, critical thinking, PAIR framework, service-learning*

Introduction

The emergence of generative artificial intelligence (Gen AI) tools—most notably marked by the release of ChatGPT in November 2022—has rapidly transformed the digital landscape. With over 100 million users just two months after its launch, as reported by Hu (2023), ChatGPT exemplifies how quickly Gen AI tools are becoming ubiquitous in both personal and professional spheres. As these tools continue to evolve and proliferate, there is growing recognition that the ability to understand, evaluate, and responsibly use Gen AI is no longer optional—it is essential.

In Singapore, this urgency is reflected in the Ministry of Education's (2023) "Transforming Education through Technology" Masterplan 2030, which emphasizes the development of emerging 21st century competencies (21CC), like critical thinking, information skills and civic literacy as a strategic thrust. Another strategic thrust in the masterplan is to strengthen the development of students' digital literacy and technology skills. AI literacy, in particular, has become a focal point, as students must be equipped not only to use Gen AI tools but also to understand their limitations, biases, and ethical implications. This would enable them to understand the characteristics of AI and leverage AI tools effectively for learning and daily living.

The initial implementation of the masterplan at the Polytechnic education level would affect students born around 2006, commonly referred to as Gen Z. Despite being labelled as digital natives, members of Gen Z often lack the deeper technological fluency required to navigate and leverage AI effectively, as reported by Marr (2022) in a Forbes report. Yet, Chan & Lee (2023) found that Gen Z students have expressed optimism about Gen AI's benefits, including enhanced productivity, efficiency and personalised learning, intending to use Gen AI for educational purposes. This disconnect justifies the need for educational institutions to proactively integrate AI education into their curricula—not just to teach technical skills, but to foster critical thinking and ethical awareness on the use of Gen AI tools.

To address this gap, recent studies have explored integrating Gen AI into high school education in various disciplines. Xie et al. (2024) have designed workshops and curricula to teach students about AI's capabilities, limitations, and ethical implications. In the study, teachers from various subjects, including humanities and STEM, participated in co-designing AI curricula, considering both technical skills and ethical debates. Chen et al. (2023) have engaged students in ChatGPT for knowledge building. These initiatives aim to develop AI literacy and critical thinking skills among youth. Zhou et al. (2023) highlighted concerns of AI-generated misinformation, which underscored the need for students to be critical of AI-generated information. Furthermore, while recognizing AI's potential benefits for learning, researchers also acknowledge challenges such as potential distractions and the need for mindful engagement with these tools in classrooms (e.g., Chen et al., 2023; Xie et al., 2024). To enable these mindful engagements, frameworks have been proposed to facilitate the integration of Gen AI into curricula. Su & Yang (2023) proposed a theoretical framework called IDEE for using Gen AI tools in education involving identifying desired outcomes, determining the level of automation, ensuring ethical considerations and evaluation effectiveness. Dickey et al. (2023) developed an AI-Lab framework for computer programming education, addressing concerns about over-dependence on Gen AI and fostering core skills development. Shanto et al. (2023) introduced PAIGE, a framework promoting assignment integrity while leveraging Gen AI's potential. Acar (2023) introduced the PAIR (Problem, AI, Interaction, Reflection) framework to guide students through a structured process of engaging with Gen AI tools, emphasizing problem formulation, exploration, experimentation, and reflection. While Acar (2023) did not anchor the PAIR framework to a particular learning theory, the emphasis of concrete experiences through problem formulation, abstract conceptualisation through AI tool selection, active experimentation through interaction, and reflective observations aligns to the four learning modes of Klob's (1984) experiential learning theory. A campus-wide study on the adoption of PAIR to purposefully infuse Gen AI into our curriculum at Ngee Ann Polytechnic was presented by Tan et al. (2024).

As part of the research, this study aims to evaluate the effectiveness of combining the PAIR framework with a project-based learning pedagogy to enhance students' AI literacy, critical thinking, and ethical reasoning. It also seeks to uncover how students perceive and engage with Gen AI tools, particularly in terms of academic integrity and the reliability of AI-generated content. By doing so, the study benefits both the students and teacher as well as contributes to the growing body of work on integrating Gen AI into education in a meaningful way.

Methodology

This study employed an action research approach as it allows for both individual self-study research and collaborative research, a flexibility that is useful when conducting research in such a nascent field. In addition, McCutcheon & Jung (1990) highlighted that through action research the intimate involvement of teacher as researcher and students as subjects in classroom activities would serve to inform and change the teacher's own practices in real-time, thereby directly benefitting the students. Zeichner (2007) has also reported that action research has the potential of contributing to both improvement of teaching practice and greater theoretical understanding.

The participants were 940 Year 1 engineering diploma students from Ngee Ann Polytechnic (NP), Singapore. These students were enrolled in a compulsory foundational module that spans across all engineering disciplines. As shown in Figure 1, the module includes a component on risk management, aligned with the Workplace Safety and Health (WSH) Council's bizSAFE Level 2 (bSL2) certification, which constitutes the discipline knowledge and skills to be taught. In addition, students were introduced to three human-centred design tools from LUMA Institute.

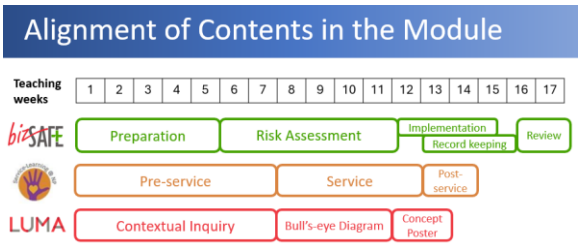

Figure 1: Existing contents in the S-L module.

Also shown in Figure 1 are the three stages of the service-learning (S-L) pedagogy that the module has adopted, which has its roots in project-based learning. Since 2016, S-L has been a signature pedagogy of NP and is modelled after the pedagogical principles defined by Bringle and Hatcher (1996). As such, S-L is a credit-bearing and discipline-based teaching approach that requires students to learn and demonstrate their acquisition of knowledge and skills through personal involvement in a service project that is intended to meet specific needs of a community.

The inclusion of AI literacy, critical thinking, and ethical awareness skills development was achieved through integration of the PAIR framework, as illustrated in Figure 2, into the bSL2 and S-L curricula.

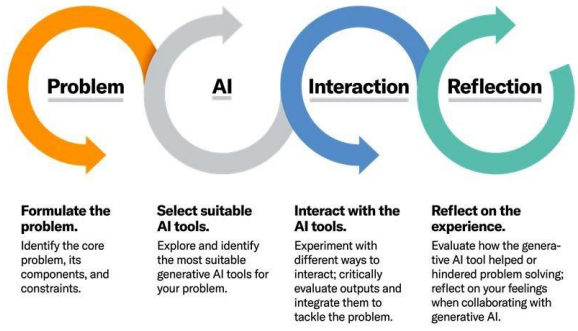

Figure 2: PAIR framework guidance by Acar (2023).

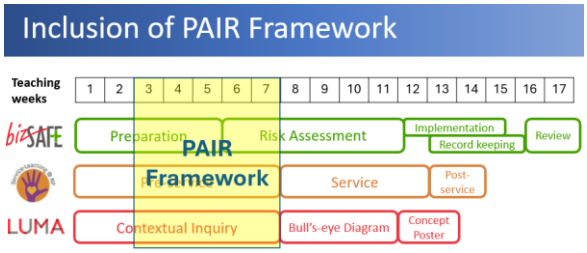

Figure 3: Inclusion of PAIR Framework in the module.

As shown in Figure 3, the PAIR framework was introduced to the students in Week 3 of the semester and spanned over 5 weeks. The four steps of the PAIR framework were integrated at four key milestones of the S-L project as shown in Figure 4.

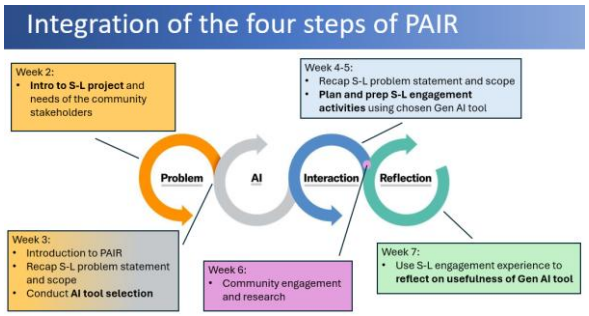

Figure 4: Integrating the four steps of PAIR.

1. Problem Formulation: Preparations for this step begun in Week 2 when students were introduced to the S-L project and needs of the community stakeholders. This was done so that by Week 3 students would have a better grasp of the scope and intent of the S-L project and thus be better prepared to identify gaps in their understanding of the community stakeholders and project.
2. AI Tool Selection: After students were introduced to the PAIR framework in Week 3 and had formulated the problem from the S-L project, they were instructed to test two Gen AI tools that they considered appropriate and useful for their research. Students then compared outputs from these two Gen AI tools, evaluated their relevance and comprehensiveness, and selected one that they considered to be better for further use.
3. Interaction: In Week 4 and 5, students interacted with their selected Gen AI tool more intensively as they prompted it to plan community engagement activities for the S-L project that incorporated safety and risk management considerations. This exercise was also referred to as desktop research during the S-L pre-service phase.
4. Reflection: Prior to the conduct of this step, students carried out the engagement activities for the community stakeholders with guidance from the plans generated by Gen AI. Throughout the delivery of activities, students recorded the hits and misses of their plans. After which, they compared their AI-generated plans with the actual outcomes and reflected on the strengths and limitations of Gen AI tools.

Data was collected through a post-project survey that included both quantitative and qualitative components:

- Quantitative: A five-point Likert scale was used to assess two broad areas, namely, students' experiences and views on using Gen AI tools and their assessment of the impact these tools had on learning and engagement. The questions for each broad areas are shown in Tables 1 and 2.

Table 1: Survey questions on experiences and views on using Gen AI tools.

1. I find the selected Gen AI tools easy to use.
2. I think the selected Gen AI tools provide relevant and helpful information.
3. I can trust the information or assistance provided by the selected Gen AI tools.
4. I am concerned about the privacy and security of my interactions with the selected Gen AI tools.
5. I am concerned about plagiarism when using the selected Gen AI tools.
6. I am concerned about becoming over-reliant on the selected Gen AI tools.

Table 2: Survey questions on impact of using Gen AI tools.

1. I think using the selected Gen AI tools helped me learn the content.
2. I developed my critical thinking skills through using the selected Gen AI tools.
3. I am engaged when using the selected Gen AI tools for learning.
4. I become more aware of the limitations of the selected Gen AI tools.
5. I improved in my ability to write prompts to generate useful outputs with the selected Gen AI tools.
6. I learnt to critically review the outputs generated by the selected Gen AI tools.

- Qualitative: Open-ended questions and personal reflections captured students' experiences with Gen AI tools, including their perceived usefulness, limitations, and ethical concerns, such as, plagiarism and privacy. The open-ended questions are shown in Table 3.

Table 3: Open-ended questions on personal perceptions and experiences.

1. Describe how your lecturer's use of Gen AI tools has helped in your learning and developing professional skills (e.g., critical thinking, problem solving, digital competency).
2. What are the Pros and Cons of using Gen AI for learning?

The survey was administered to all students by inserting it as a pre-assignment submission task during the S-L post-service phase.

Quantitative data were analysed using descriptive statistics to identify trends in students' responses. Qualitative data from reflections and open-ended survey

responses were thematically analysed to uncover deeper insights into students' learning experiences and attitudes toward Gen AI.

Results and Discussion

The results and discussion are presented in the following three areas, namely, Area 1: Quantitative response on students' experiences and views on using Gen AI tools, Area 2: Quantitative response on students' assessment of the impact Gen AI tools had on their learning and engagement, and Area 3: Qualitative response of the three open-ended questions.

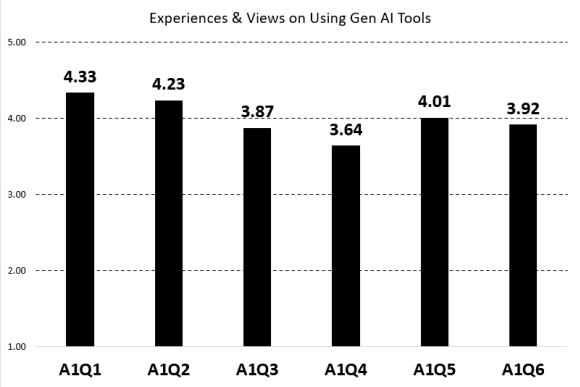

Figure 5: Responses for experiences and views on using Gen AI tools.

With reference to Figure 5, the survey results indicate that students generally had positive experiences using Gen AI tools. The highest-rated items were ease of use (4.33) and the relevance of information provided (4.23), suggesting that students found the tools accessible and helpful for their tasks. Many students gravitated toward GenAI tools they were already familiar with, which likely influenced their selection based on comfort and perceived reliability. During the AI tool selection stage, students often chose the tool that returned more comprehensive and contextually relevant results, reinforcing the importance of usability and output quality in their decision-making process.

The mid-tier scores for plagiarism (4.01), over-reliance (3.92) and trust (3.87) could indicate a growing sense of caution in using Gen AI tools as opposed to embracing it as a do-it-all tool when it was first launched. The ethical concerns around plagiarism could be triggered by the institutional use of plagiarism detection software, Turnitin. The relatively lower score for trust might have arisen from students' experiences comparing AI-generated content with real-world findings during their service-learning projects. Consequently, these two factors could have tampered students' attitudes towards becoming over-reliant on Gen AI tools. The lowest rating for concerns about privacy of interactions (3.64) could indicate that while students are cautious about academic integrity and reliance on Gen AI, they may not yet fully grasp the broader implications of data security in their usage of these tools. This could be because of the scope of interactions, which in this case was generally for school work and thus impersonal in nature.

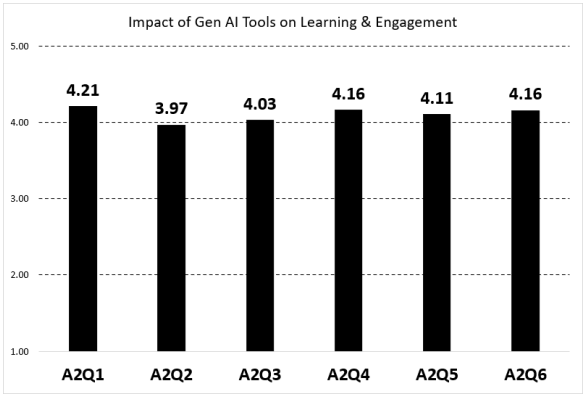

Figure 6: Responses for impact of Gen AI tools on learning and engagement.

Based on the results shown in Figure 6, students felt that Gen AI tools generally had a positive impact on their learning and engagement. They think that these tools supported their understanding of content (4.21), which reinforces the perception that students use Gen AI as a tool for information retrieval and sense making. In addition, their awareness of Gen AI limitations (4.16) may have been fostered by the PAIR AI tool selection and Reflection stages. On the other hand, the contrasting ratings for learning to critically review Gen AI outputs (4.16) and developing critical thinking skills through Gen AI usage (3.97) may suggest that the PAIR AI tool selection and Reflection exercises gave more avenues to learn critical thinking than when Gen AI tools were being used during the Interaction stage. This is because the AI tool selection and reflection stages encouraged students to evaluate the quality and limitations of AI-generated outputs, contributing to a deeper awareness of the tools' capabilities and constraints. Students also rated improvements in their ability to write prompts highly (4.11), which is notable given that no formal instruction on prompt engineering was provided. The development of this skill appears to have emerged organically through self-guided exploration and iterative use of the tools, thereby highlighting the potential of experiential learning in AI education. The rating that students had for their perceived engagement level with Gen AI tools was relatively lower (3.97). This may be attributed to the way in which these tools were being used, that is, as a typical search engine.

An analysis of the comments from the open-ended question on "Describe how your lecturer's use of Gen AI tools has helped in your learning and developing professional skills." revealed that critical thinking emerged as the most prominent theme. Students frequently mentioned that comparing outputs from different Gen AI tools and evaluating the accuracy of responses helped them develop a more analytical mindset. This was particularly evident during the AI tool selection and reflection stages of the PAIR framework, where students were encouraged to assess the quality and relevance of AI-generated content. Comments about the

limitations of Gen AI tools and the importance of fact-checking and contextual understanding were also seen. This awareness aligns with the lower trust scores observed in the quantitative data and underscores the need for continued emphasis on responsible AI use.

In response to the question, "What are the Pros and Cons of using Gen AI for learning?", students provided a range of insights that reflect both the benefits and challenges of integrating Gen AI tools into educational contexts. A thematic analysis of responses revealed a few recurring themes as summarized in Tables 4 and 5.

Table 4: Themes related to the benefits of using Gen AI for learning.

Theme	Supporting points
Efficiency and Speed	Many appreciated the ability of Gen AI tools to provide quick answers and streamline the research process.
Idea Generation	Students found Gen AI helpful for brainstorming and exploring alternative perspectives.
Accessibility	The 24/7 availability of Gen AI tools was seen as a major benefit, especially for independent learning.
Clarification and Support	Gen AI was often used to clarify doubts and reinforce understanding of complex topics.
Personalized Learning	Some students noted that Gen AI tools could adapt to their individual learning needs, offering tailored support.

Table 5: Themes related to the challenges of using Gen AI for learning.

Theme	Supporting points
Over-Reliance	A key concern was that excessive dependence on Gen AI could hinder the development of critical thinking and independent problem-solving skills.
Inaccuracy	Students were aware that Gen AI tools can sometimes provide outdated or incorrect information, necessitating verification.
Plagiarism and Ethical Risks	The temptation to copy AI-generated content raised concerns about academic integrity.
Loss of Creativity and Self-Learning	Some students felt that relying on Gen AI could reduce their motivation to explore topics independently.
Privacy and Data Security	A few responses mentioned concerns about how personal data might be used or stored by Gen AI platforms.

These findings reinforce the importance of guided use of Gen AI tools in educational settings. While students recognize the value of these tools in enhancing learning, they also understand the need for critical engagement and ethical use.

Conclusions

This study explored the integration of the PAIR framework into a service-learning module to enhance the teaching of Gen AI skills among Year 1 engineering diploma students. Anchored in Singapore's national push to develop 21st century competencies, the study aimed to foster AI literacy, critical thinking, and ethical awareness through authentic, community-based learning experiences.

Quantitative survey results revealed that students generally found Gen AI tools easy to use and helpful in supporting their learning. They reported gains in AI literacy and digital competency, with many acknowledging improvements in their ability to write prompts and critically evaluate AI-generated outputs. However, the findings also highlighted areas of concern, including moderate levels of trust in Gen AI tools and limited awareness of privacy and security risks.

Qualitative responses further enriched these insights. Students valued the efficiency, accessibility, and idea-generation capabilities of Gen AI tools, but also expressed concerns about over-reliance, potential inaccuracies, and ethical risks such as plagiarism. Thematic analysis of open-ended responses underscored the importance of guided use, with students benefiting most when Gen AI tools were embedded meaningfully into structured learning activities.

Nevertheless, the survey results and qualitative responses may be affected by self-reporting biases, such as, recall bias and social desirability bias, as it was administered prior to an assignment submission milestone to achieve the maximum response rate. Moreover, there could be measurement inconsistencies arising from students' interpretations of attributes, such as, critical thinking and problem solving.

Overall, the integration of the PAIR framework into the S-L module proved to be a promising approach for introducing Gen AI in a way that balances technological fluency with critical reflection. As Gen AI tools become increasingly prevalent in education and the workplace, it is essential that students are not only equipped to use them effectively but also to question, evaluate, and apply them responsibly. Future iterations of this module could benefit from more intentional instructions on prompting techniques, showing examples of ethical Gen AI use, and highlighting privacy and data security concerns of Gen AI use. This will hopefully ensure that students are prepared to navigate the evolving digital landscape with confidence and integrity.

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