Leveraging the PAIR Framework and Generative AI to Enhance Self-Directed Learning

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Self-directed learning (SDL) is an essential skill for lifelong learning, enabling individuals to continuously adapt to evolving challenges and demand. It empowers students to take the initiative, set learning goals, and manage their own learning processes (Brandt, 2020). However, without structured guidance, students often face challenges such as lack of immediate feedback, difficulty in finding relevant learning resources, limited engagement in problem-solving, and inadequate reflection on their learning progress. These issues often result in frustration, reduced motivation, and ineffective learning outcomes, highlighting the need for guidance and strategies to support SDL effectively.

This paper explores how Generative AI (GenAI) enhances SDL by leveraging on the PAIR framework (Acar, 2023), developed by Professor Oguz Acar to encourage the purposeful adoption of GenAI in the curriculum. The study was conducted with a group of Year 2 Diploma in Information Technology students from Ngee Ann Polytechnic who were enrolled in the Mobile Application Development (MAD) module. In this module, students worked in teams to design and develop a real-world mobile application, applying their knowledge of mobile app development concepts and tools. The PAIR framework's four phases (Problem Formulation, AI Tool Selection, Interaction, and Reflection) were integrated into the assignment with GenAI-powered tools that offered real-time feedback and interactive problem-solving support to mitigate common SDL pitfalls. In the Problem Formulation phase, students identify key challenges in their projects, promoting critical thinking and structured problem-solving. GenAI supports students by breaking complex problems into manageable tasks, helping students structure their approach before starting development work. In the AI Tool Selection phase, students evaluate and choose the most appropriate GenAI tools to address their identified challenges. This phase strengthens decision-making skills as students assess various AI solutions across development tasks such as coding, debugging, and UI/UX design. During the Interaction phase, students actively engage with the selected GenAI tools to experiment, generate solutions, and refine their work. GenAI provides real-time feedback, suggests improvements, and offers alternative solutions to further strengthen problem-solving abilities. Finally, in the Reflection phase, students evaluate their learning process, analyse the quality of AI-generated solutions and refine their approach for continuous improvement. After completing the assignment, 91 students responded to a survey, sharing their experiences with GenAI and its impact on their learning. The survey results show that integrating GenAI through the PAIR framework enhanced students SDL by fostering goal setting, resource evaluation, problem-solving, and reflective thinking. This structured approach not only addressed immediate project challenges but also strengthened core SDL competencies in a project-based learning environment.

Keywords: *Self-directed Learning, Generative AI, PAIR Framework, Software Engineering*

Introduction

In an age of information abundant and rapid change, self-directed learning (SDL) has become a foundational competency for both academic success and lifelong learning (Tan, 2014). SDL empowers students to take ownership of their education journeys by identifying their learning needs, setting personal goals, finding suitable resources, implementing learning strategies, and evaluating their outcomes (Knowles, 1975; Garrison, 1997). This sense of autonomy is especially important in technology-driven fields, where learners must continuously adapt to new tools, frameworks, and problem-solving contexts. The importance of cultivating SDL is also emphasized in Singapore's EdTech Masterplan 2030, which highlights technology-enabled personalization as a key driver for nurturing independent learners (2023). When students are equipped to learn independently, they are more likely to develop critical thinking, resilience, and adaptability skills that are essential for employability and long-term success (Candy, 2004).

Many students struggle to cultivate effective SDL habits such as goal setting, time management, information literacy, reflective thinking, and self-assessment are not always intuitive and often require deliberate scaffolding. Without structured support, students may feel uncertain about where to begin, how to organize their learning, or which strategies to employ. This challenge becomes more pronounced in project-based environments like software development, where learners must navigate open-ended tasks, define functional requirements, solve technical problems, collaborate with peers, and produce usable outcomes. Common challenges include idea generation, using unfamiliar development tools, debugging code, and engaging in meaningful reflection on learning strategies (Loeng, 2020; Chou & Chen, 2008). By grounding these challenges in established SDL theory, educators and researchers can more precisely identify intervention points to help students build lasting, transferable learning competencies.

To support SDL, traditional instructional methods have often incorporated scaffolding strategies such as formative feedback, structured rubrics, peer collaboration, and reflective journals (Hmelo-Silver, 2004; Zimmerman, 2002). While these approaches have been shown to enhance students' engagements and improve learning outcomes, they also present notable limitations. They can be time-consuming for instructors to implement, their effectiveness may vary across different student groups, and they often lack the level of personalization required to address individual learning gaps. Most critically, such strategies frequently fall short in providing just-in-time support when students encounter technical challenges or struggle to comprehend complex concepts during independent study.

The rise of GenAI tools such as ChatGPT, Claude, and Microsoft Copilot have opened powerful new avenues for addressing the limitations of traditional SDL support. These tools can assist students by generating explanations, producing code, suggesting alternative solutions, and guiding problem-solving in real-time. However, their educational value depends largely on how purposefully and ethically they are integrated into the learning process. Without proper structure, students may become overly reliant on AI-generated content, resulting in shallow understanding or issues related to academic integrity (Kasneci et al., 2023).

To bridge this gap, the PAIR framework developed by Prof Oguz A. Acar of King's College London aims to provide a balanced approach to integrating AI in learning. The framework aligns with key stages of the SDL process: identifying and articulating the learning challenge, critically selecting appropriate AI tools, actively engaging with these tools to develop and refine solutions and finally reflecting on the outcomes to enhance future learning strategies.

To evaluate the effectiveness of the PAIR framework, a study was conducted with Year 2 students from the Diploma in Information Technology programme at Ngee Ann Polytechnic, who were enrolled in the Mobile Application Development (MAD) module. In this module, students worked in teams to design and build real-world mobile applications.

This paper presents finding that examine how the PAIR framework, when combined with GenAI tools, can address common SDL challenges and foster more effective, independent learning in a tertiary education setting.

Research Design and Methodology

This study was conducted as part of the MAD module, a project-based module offered to 91 Year 2 students in the Diploma in Information Technology programme at Ngee Ann Polytechnic.

The MAD curriculum requires students to understand key Android development concepts. However, many students encountered challenges such as generating viable app ideas, navigating the Android development environment, debugging complex code, and managing version control using GitHub. To address these challenges and foster SDL, GenAI tools were integrated into the assignment through the PAIR framework, which provided a structured approach to guide meaningful AI engagement during scoping, implementation, debugging, and reflection.

The PAIR framework comprising four stages: Problem Formulation, AI Tool Selection, Interaction, and Reflection as depicted in Figure 1 was deliberately embedded into key phases of the assignment to scaffold SDL. Students were introduced to GenAI tools such as ChatGPT and Microsoft Copilot and were guided on their purposeful use at each stage. During the Problem Formulation stage, students used GenAI to brainstorm and refine app ideas, define user needs, and articulate functional requirements. In the AI Tool Selection stage, they evaluated suitable tools for tasks such as code generation, UI prototyping, and logic implementation. The Interaction stage involved hands-on use of GenAI to implement features, debug issues, and iterate on their designs. Finally, the Reflection stage encouraged students to critically assess their learning strategies, tool usage, and team dynamics. The PAIR framework aligns with Garrison's (1997) three dimensions of SDL by fostering: 1) self-management through structured planning where learners set learning goals, 2) self-monitoring through iterative problem-solving where learners actively track their progress, and 3) motivation through purposeful resource selection and reflective evaluation of learning outcomes.

Over the course of an 18-week semester, students worked in teams of four to design, develop, and deliver a fully functional Android mobile application. The objectives of the assignment were to: 1) demonstrate the ability to implement a mobile application; 2) encourage thoughtful and practical app design; 3) support students in identifying their individual learning needs based on selected app features; 4) promote active engagement in the development process through the iterative design and implementation of app features; and 5) to prepare students for possible app deployment on the Google Play Store.

This paper focuses on Stage 1 of the assignment, a critical 7-week phase that accounted for 30% of the overall module grade. This phase emphasized early-stage project planning, including problem formulation, feature scoping, and prototyping, making it well suited to examine how GenAI-supported SDL practices influenced student engagement and learning strategies.

As part of Stage 1, teams selected an app category from a predefined list as shown in Figure 2, which included domains such as Education, Health & Fitness, Travel & Local, Tools, Lifestyle, and Communication. Based on the selected category, students conceptualised and implemented the core functionality of their mobile application. Each team was required to integrate at least three technical features, such as: responsive layouts, multimedia components (images, video, audio), RecyclerView, or data persistence using SQLite, or SharedPreferences.

To support both collaboration and SDL, each team maintained a GitHub repository to manage source control, track progress, assign roles, and document their development progress. They also submitted a project proposal outlining the app concept, team structure, and planned features.

The deliverables for Stage 1 included: 1) a working prototype incorporating the required features; 2) a GitHub repository with documentation of the app concept, features, task allocation, and development timeline; 3) a team presentation covering the app's purpose, technical decisions, and overall development workflow; and 4) an individual reflection describing how GenAI tools supported their learning across the four phases of the PAIR framework.

Data Collection

To evaluate the effectiveness of GenAI-supported SDL within the context of the PAIR framework, data was collected through an individual reflection survey administered at the end of Stage 1 of the MAD assignment. The survey aimed to capture students' experiences with GenAI tools, structured around the four PAIR phases: Problem Formulation, AI Tool Selection, Interaction, and Reflection.

The reflection survey was conducted online using Microsoft Forms. It comprised open-ended questions aligned with each PAIR phase to gather qualitative insights on how students engaged with GenAI tools

The survey questions were categorized into the four PAIR phases as follows:

In the Problem Formulation phase, students were asked to describe the key challenges encountered during their assignment, such as difficulties with ideation, layout design, coding logic, or debugging. This question assessed their ability to independently identify and articulate problems.

Q1. What is/are the problem(s) you encountered in your Assignment 1?

For the AI Tool Selection phase, students reflected on how they selected and evaluated GenAI tools, considering factors such as relevance, ease of use, and familiarity. This phase focuses on understanding their decision-making process when choosing tools to address specific challenges.

Q2. What were the considerations did you have in selecting the GenAI tool to assist you in resolving the problem(s)?

Q3. Please indicate the GenAI tool(s) you used for the assignment.

In the Interaction phase, students explained how they used the selected GenAI tools, the usefulness of the generated outputs, and how these were integrated into their project work. This phase explored how students engaged with GenAI to support their problem-solving process.

Q4. How useful were the solutions provided by the GenAI tool. Please share your experience.

Q5. How were these solutions used in your assignment? Please elaborate in detail.

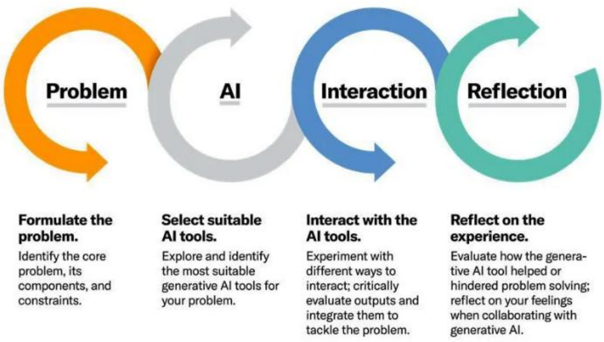

Figure 1 PAIR Framework

Daydream	Health & Fitness	Shopping
Beauty	House & Home	Social
Business	Libraries & Demo	Sports
Comics	Travel & Local	Tools
Communication	Video Players & Editors	Weather
Dating	Wear OS by Google	Lifestyle
Education	Map & Navigation	Medical
Entertainment	Music & Audio	Parenting
Events	Books & Reference	Personalization
Finance	Art & Design	Photography
Editors	Auto & Vehicles	Productivity
Food & Drink	News & Magazines	

Figure 2 App Category

Finally, in the Reflection phase, students assessed the overall impact of GenAI on their learning, highlighting both benefits and limitations. This phase encouraged metacognitive reflection on the value of AI-assisted learning.
Q6. Reflect on your experience in using GenAI tools for your assignment - did GenAI provide you with more/less help to resolve the problem? Please share your thoughts.

The responses gathered from the reflection survey served as the primary dataset for evaluating how the structured use of GenAI tools, scaffolded by the PAIR framework, influenced students' SDL experiences. The qualitative data was then analysed to identify patterns related to confidence in problem-solving, tool effectiveness, decision-making strategies, and reflective learning behaviours.

Results and Discussion

A total of 91 students responded to the reflection survey. In Q1, students were asked to describe the problems they encountered during Assignment 1. Figure 3 illustrates the six main categories of challenges students faced, with debugging and technical implementation as the most significant barriers.

Debugging challenges were the most prevalent, with 68.1% of students reporting difficulties in resolving code errors. This highlights the critical need for timely and accessible support, especially in project-based learning environments where immediate problem-solving is crucial. Technical implementation was the second most cited issues (58.2%), with students struggling to integrate core Android components such as Firebase, RecyclerView, and custom user interfaces. These results point to a broader difficulty in translating conceptual ideas into functioning features.

Other challenges included data persistence (26.4%), particularly in managing SQLite databases or using SharedPreferences. Ideation and concept design (19.8%), where students found it difficult to define app idea and project scope. Navigation and user interface (UI) logic (17.6%), including issues with screen transitions and button interactions. The least reported challenge was multimedia integration (5.5%), involving difficulties with embedding audio, video or images.

These findings reveal that students' primary challenges lay in the implementation phase rather than idea generation, it also reflecting the real-world complexity of mobile app development. The variety of challenges reported highlights the importance of targeted scaffolding. Integrating GenAI tools within the PAIR framework, particularly during Problem Formulation, enabled students to better scope, prioritize, and deconstruct development tasks. This approach reinforced SDL outcomes by empowering students to tackle technical barriers early in the project.

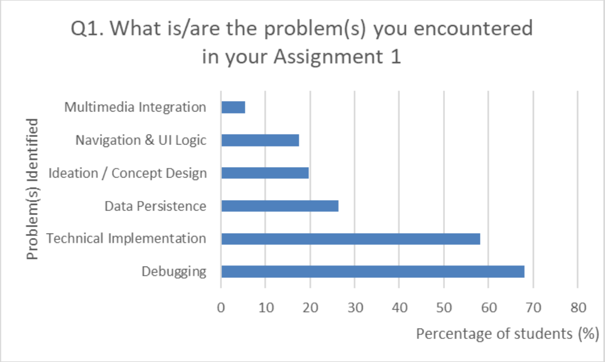

Figure 3 Problem formulation findings

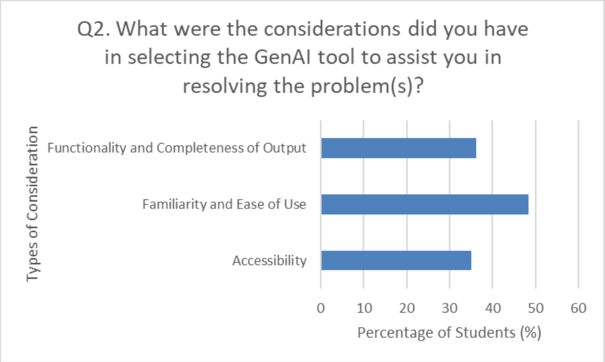

Figure 4 Considerations for selecting GenAI tools

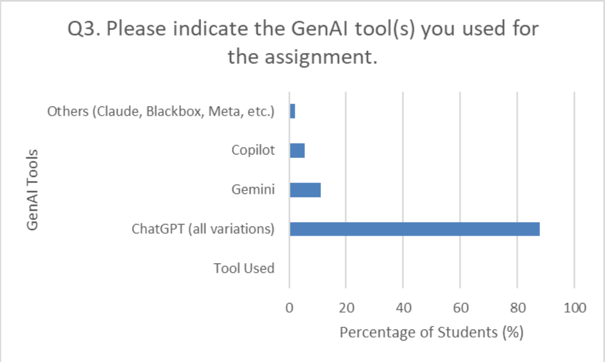

Figure 5 GenAI tools used by students

Figure 4 shows the results from Q2, which explored students' consideration when selecting GenAI tools for their assignment. Students primarily based their choices on three key factors: familiarity, accessibility, and practical utility. Nearly half of the respondents (48.4%) preferred tools they found intuitive or had prior experience with 35.2% selected tools that were freely accessible, while 36.3% valued tools that produced complete and usable outputs, allowing for immediate application to their technical tasks.

Figure 5 shows 88% of students identified Chat GPT as their GenAI Tool of choice in Q3. Its popularity can be attributed to its accessibility, familiarity, and broad applicability across wide range of development challenges. In contrast, approximately 11% of students reported using Google Gemini, likely due to its integration with Google services or preference for its alternative response styles. A smaller proportion explored other tools, such as Microsoft Copilot (5%) and specialised platforms such as Claude and Blackbox AI (2%).

The combined results from Q2 and Q3 reveal students' developing digital literacy and their growing ability to strategically select appropriate learning resources, a key competency in SDL. Their ability to evaluation tools based on reliability, usability, and alignment with their learning goals demonstrates engagement with the AI Tool Selection phase of the PAIR framework. Notably, some students also explored lesser-known tools, indicating a willingness to evaluate options beyond familiarity, which is a sign of maturing SDL where learners adapt tool use to specific task demands.

Q4 and Q5 focused on how students interacted with GenAI tools and their perceived usefulness. Figure 6 shows more than half of the students (57.1%) rated GenAI tools as highly useful, particularly for debugging, generating code snippets, and clarifying Android specific concepts. These students reported that GenAI tools accelerated their progress and provided on-demand support that was often not available through traditional learning resources. 23% of respondents found the tools as moderately useful, noting AI-generated content often required additional refinement. Approximately 8.8% of students found the tools as minimally useful, citing challenges such as irrelevant or unclear output responses. The remaining about 9.9% of responses lack sufficient detail for classification.

Figure 7 illustrates how students applied AI-generated solutions in their development work. The most common use case was code debugging (69.2%), followed by code generation (57.1%), demonstrating students leaned on GenAI for technical execution. Many used ChatGPT to correct syntax errors, refine logical flaws, or generate code snippets aligned to their assignment requirements. About 33% of students used GenAI to assist in UI design and layout, especially for refining XML and achieving responsive interfaces. A smaller group (16.5%) used GenAI to strengthen conceptual understanding, such as clarifying Android lifecycle methods or Firebase integration.

These findings show that students engaged with GenAI purposefully, tailoring their use based on individual learning goals. Rather than relying on GenAI for rote answers, most students applied the outputs contextually and critically. This behaviour aligns with the Interaction phase of the PAIR framework, where learners experiment, learn through iteration, and adapt their solutions through feedback which is the core habits of effective SDL.

Q6 captured students' reflection on their overall experience with GenAI. As illustrated in Figure 8, 53.8% reported positive experiences, stating that GenAI enhanced their problem-solving efficiency and helped

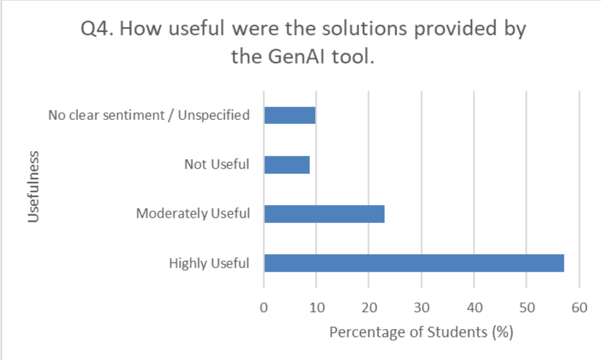

Figure 6 Perceived usefulness of GenAI tools

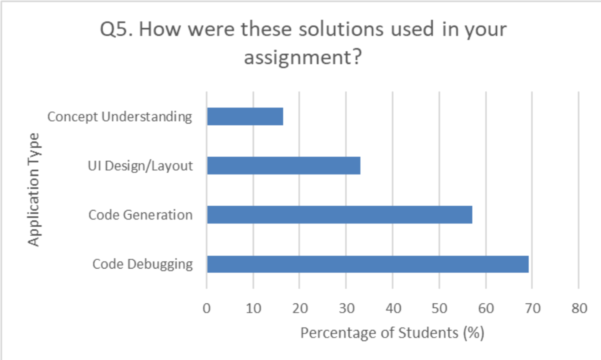

Figure 7 Interaction with GenAI solutions

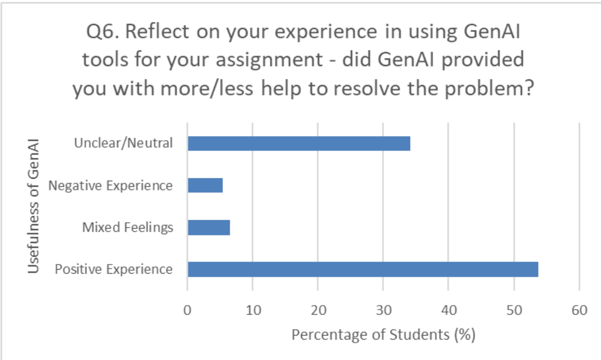

Figure 8 Students refection on GenAI learning support

them manage unfamiliar technical challenges. About 40.7% of students shared neutral or mixed reflections with limitations such as inaccurate or overly generic responses. A small group (5.5%) reported negative experiences, citing confusing or unhelpful outputs that hindered their learning.

These reflections show that while students generally valued GenAI support, many also demonstrated awareness of its limitations. Their ability to critically assess the strength and shortcomings of AI-generated assistance indicates developing metacognitive awareness, a key element of SDL. This aligns with the Reflection phase of the PAIR framework, where learners evaluate not just outcomes but also the tools and strategies used contributed to their learning process, ultimately fostering more intentional and deeper learning over time.

While these findings are exploratory and rely on students' self-reported perceptions, they provide initial evidence that PAIR-guided GenAI integration can meaningfully support the development of SDL competencies in project-based learning.

Conclusions

This study investigated how GenAI tools enhance SDL in a project-based MAD module, guided by the PAIR framework's four phases: Problem Formulation, AI Tool Selection, Interaction, and Reflection. Analysis of 91 student responses revealed that GenAI tools in particular ChatGPT served as effective learning companions when used purposefully. Students reported substantial benefits in multiple areas such as problem scoping, code generation, debugging, and conceptual understanding, with over half indicating the tools were highly useful in supporting their learning process. The structured integration of GenAI through the PAIR framework successfully scaffolded key SDL practices such as goal setting, resource evaluation, experimentation, and reflection.

The results also highlighted important variations in students' perception and utilisation of GenAI. While many demonstrated confidences in applying AI tools effectively, others offered mixed or ambiguous reflections, indicating varying levels of digital literacy and metacognitive awareness. These insights underscore the need for continued scaffolding to promote ethical, critical, and purposeful use of AI in education contexts.

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