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FROM SET THEORY TO MARKETPLACE APPLICATIONS DEVELOPMENT: AN AI-ASSISTED CASE-TO-PROJECT LEARNING APPROACH IN DISCRETE MATHEMATICS

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ABSTRACT

Purpose: Set Theory is a fundamental yet abstract topic in Discrete Mathematics that often challenges students in connecting mathematical concepts with real-world applications. This study proposes an AI-Assisted Case-to-Project Learning approach that transforms Set Theory learning into marketplace application development while fostering interdisciplinary and digital competencies.
Design/methodology/approach: A convergent mixed-methods design was employed involving 50 undergraduate vocational students organised into ten project teams. Students first analysed Set Theory through the Shopee marketplace, then investigated different domestic and international marketplaces before developing simplified marketplace applications using HTML, CSS, JavaScript, and Generative AI. The project integrated Programming, Database Systems, Computer Architecture, and Marketing, with Set Theory serving as the conceptual foundation. Data were collected through competency-based assessment rubrics, project documentation, and application analysis.
Findings: All project teams successfully developed functional marketplace applications featuring product catalogues, seller and buyer interactions, digital payment options, and delivery services. The findings demonstrate that students effectively translated abstract Set Theory concepts into authentic digital solutions while Generative AI supported mathematical modelling, programming, debugging, and iterative problem solving.
Research limitations/implications: The study was conducted in a single vocational higher education institution, limiting the generalisability of the findings.
Practical implications: The proposed approach provides an authentic instructional framework that connects mathematical reasoning with interdisciplinary software development and computational thinking.
Originality/value: This study introduces an AI-Assisted Case-to-Project Learning approach that positions Set Theory as the conceptual backbone of marketplace application development, enabling students to integrate mathematical reasoning, Generative AI, and interdisciplinary knowledge in solving authentic problems.
Paper type: Research paper
Keyword: Discrete Mathematics; Set Theory; Case-to-Project Learning; Generative AI; Marketplace Application Development; Computational Thinking.

A. INTRODUCTION

The rapid advancement of digital technologies has significantly reshaped the competencies expected from graduates in vocational higher education, particularly in computing-related disciplines. Beyond mastering programming skills, students are increasingly required to integrate mathematical reasoning, computational thinking, and problem-solving abilities to address authentic digital challenges (Zhang and Aslan, 2021; Goos, Carreira and Namukasa, 2023; Mudinillah *et al.*, 2024; Cañavate, Martínez-Marroquín and Colom, 2025; Bîzoi and Bîzoi, 2026). However, achieving

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this integration remains a persistent challenge in Discrete Mathematics education, where abstract concepts are often presented through symbolic representations and routine exercises with limited connection to real-world applications. Consequently, students frequently struggle to transfer mathematical knowledge into practical computing contexts, reducing both conceptual understanding and learning engagement. These challenges have encouraged educators to explore instructional approaches that promote meaningful learning by connecting mathematical concepts with authentic digital environments.

To address these challenges, previous studies have investigated various instructional approaches, including contextual learning, case-based learning, and project-based learning, to improve students' mathematical understanding and engagement. Contextual learning has been shown to facilitate conceptual understanding by linking abstract mathematical ideas with situations that students encounter in everyday life, while project-based learning encourages active knowledge construction through authentic problem solving (Roach, Tilley and Mitchell, 2018; Lim *et al.*, 2023; Ajjawi *et al.*, 2024; Quinlan, Sellei and Fiorucci, 2025). In computing education, digital platforms and real-world systems have increasingly been incorporated into mathematics instruction to enhance relevance and motivation. Nevertheless, many existing approaches primarily emphasise contextual analysis or project completion independently, providing limited opportunities for students to transform mathematical concepts into functional digital applications that integrate both conceptual reasoning and software development.

Alongside these pedagogical developments, Generative Artificial Intelligence (Generative AI) has rapidly emerged as a transformative technology in higher education. Recent studies have demonstrated its potential to support personalised learning, mathematical exploration, programming assistance, debugging, and immediate feedback, enabling students to engage more actively in complex learning tasks. Within mathematics education, Generative AI has been recognised as a valuable learning partner that facilitates conceptual understanding rather than merely providing answers (How and Hung, 2019; Dias Rasteiro and Thiele, 2024; Stefanova and Georgiev, 2024; Garcia *et al.*, 2025). Despite these promising findings, the integration of Generative AI into Discrete Mathematics education remains relatively underexplored, particularly in learning environments that require students to apply abstract mathematical concepts throughout the complete process of analysing, designing, and developing authentic digital solutions.

Although contextual learning, project-based learning, and AI-assisted learning have individually demonstrated positive educational outcomes, several important gaps remain. First, relatively few studies have investigated how authentic marketplace platforms can be utilised as meaningful contexts for learning Set Theory beyond conceptual illustration. Second, limited research has integrated contextual case analysis with project-based application development within a unified instructional framework. Third, empirical evidence regarding the role of Generative AI in supporting students to transform abstract Set Theory concepts into functional software applications is still scarce. Addressing these gaps requires a learning approach that simultaneously promotes conceptual understanding, computational thinking, interdisciplinary collaboration, and authentic application development.

Accordingly, this study proposes an AI-Assisted Case-to-Project Learning approach that transforms Set Theory learning from contextual marketplace analysis into marketplace application development. Through this approach, students first investigate the implementation of Set Theory within authentic marketplace environments before employing Generative AI to support the design and development of simplified marketplace applications. Rather than positioning Set Theory as an isolated mathematical topic, the proposed approach places it at the centre of interdisciplinary software development, enabling students to connect mathematical reasoning with computational implementation. Therefore, this study aims to investigate the implementation of AI-Assisted Case-

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to-Project Learning in a Discrete Mathematics course and examine how the proposed approach supports students in translating abstract Set Theory concepts into authentic digital applications.

Theoretical Foundation

This study is grounded in four complementary theoretical perspectives that collectively explain how abstract mathematical concepts can be transformed into authentic software development experiences through AI-assisted learning. These perspectives include constructivist learning theory, situated learning, project-based learning, and generative AI as cognitive scaffolding. Together, they provide a coherent foundation for the proposed AI-Assisted Case-to-Project Learning approach, which integrates mathematical reasoning, authentic problem-solving, collaborative project development, and AI-supported learning.

Constructivist learning theory argues that knowledge is actively constructed through learners' interactions with meaningful experiences rather than passively received from instructors (Olusegun, 2015; Suhendi, Purwarno and Chairani, 2021). Within mathematics education, students develop conceptual understanding by connecting abstract ideas with real-world contexts and collaboratively refining their reasoning. In this study, Set Theory was not introduced merely as a collection of mathematical definitions but as a conceptual framework for analysing relationships among users, products, transactions, and payment systems within marketplace platforms. This constructivist perspective enabled students to build their own understanding before applying mathematical concepts to software development tasks.

Situated learning emphasizes that meaningful learning occurs when knowledge is acquired within authentic social and professional contexts (Zhang, Wang and Xu, 2024; Tachie-Menson and Rosca, 2025). Instead of solving isolated mathematical exercises, students investigated the structure and business processes of existing marketplace platforms such as Shopee before designing their own applications. By embedding Set Theory within familiar digital commerce environments, students experienced how mathematical concepts operate in realistic situations. This authentic context strengthened conceptual understanding while simultaneously connecting mathematics learning with vocational competencies required in software and information technology development.

Project-Based Learning (PBL) provides opportunities for learners to integrate knowledge, technical skills, and collaboration through the completion of authentic products (Kolova and Belkina, 2021; Ahmad *et al.*, 2023; Mudinillah *et al.*, 2024; Novalia *et al.*, 2025). However, this study extends conventional PBL by introducing a Case-to-Project sequence in which students first analyse an existing marketplace as a case before transforming their findings into a functional marketplace application. This progression encourages learners to bridge mathematical modelling with programming implementation, allowing Set Theory to become the conceptual foundation of application development rather than remaining as an isolated theoretical topic.

Generative Artificial Intelligence serves as a cognitive scaffold that supports learners throughout the software development process. Rather than replacing mathematical reasoning or programming competence, AI assists students in generating interface ideas, explaining programming syntax, debugging code, and refining application features (Paulauskaite-Taraseviciene *et al.*, 2022; Balart and Shryock, 2024; Liu, Wang and Wang, 2025). Students remain responsible for constructing mathematical models, validating AI-generated outputs, and making design decisions. Consequently, AI functions as an intelligent learning partner that enhances problem-solving efficiency while preserving students' active engagement in conceptual reasoning and application development.

Collectively, these four theoretical perspectives establish a coherent pedagogical foundation for AI-Assisted Case-to-Project Learning, explaining how abstract mathematical concepts can be transformed into authentic marketplace application development through contextual learning, collaborative project work, and AI-supported problem solving. Table 1 summarizes the contributions

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of each theoretical perspective to the proposed AI-Assisted Case-to-Project Learning model and its implementation in this study. The integration of these theoretical perspectives forms the conceptual foundation of the proposed learning model, as illustrated in Figure 1.

Tabel 1. Theoretical Foundations Supporting AI-Assisted Case-to-Project Learning

Theoretical Perspective	Core Concept	Contribution to This Study
Constructivist Learning Theory	Knowledge is actively constructed through meaningful experiences.	Supports students in constructing Set Theory concepts through marketplace analysis before application development.
Situated Learning in Authentic Context	Learning becomes meaningful when situated in authentic contexts.	Positions marketplace platforms as authentic contexts that connect mathematical concepts with real-world digital commerce.
Project-Based Learning	Learning is achieved through developing authentic products.	Guides students from analysing marketplace cases to designing functional marketplace applications.
Generative AI as Cognitive Scaffolding	AI supports learning by providing guidance rather than replacing learners' thinking.	Assists coding, debugging, interface design, and problem-solving while maintaining students' responsibility for mathematical modelling and software development.

B. METHODOLOGY

This study employed a convergent mixed-methods design to comprehensively evaluate the implementation of an AI-Assisted Case-to-Project Learning approach in a Discrete Mathematics course. A mixed-methods approach was considered appropriate because the study aimed not only to measure students' learning outcomes but also to explore how they translated abstract Set Theory concepts into authentic marketplace application development (Karabulut-Ilgu and Jahren, 2016; Blayone *et al.*, 2018; Younas, Fàbregues and Creswell, 2023; Katz-Buonincontro, 2024). Quantitative data were used to assess students' competencies through structured assessment rubrics, whereas qualitative data provided deeper insights into students' learning processes, project artefacts, and the implementation of mathematical concepts within the developed applications. Both datasets were collected during the same instructional period, analysed independently, and subsequently integrated to obtain a comprehensive understanding of the effectiveness of the proposed learning approach.

The study involved 50 first-year undergraduate students enrolled in the Discrete Mathematics course in the Diploma Program of Informatics Engineering at Politeknik Negeri Semarang, Indonesia. Participants were selected using purposive sampling because they were undertaking Set Theory as part of the regular curriculum during the semester in which the study was conducted. Students were organised into ten collaborative teams, each consisting of five members, to facilitate case analysis, project development, and peer collaboration throughout the learning activities. All participants completed the entire learning intervention and consented to the use of anonymised learning data for research purposes.

The learning intervention was implemented over four consecutive stages. First, the instructor introduced Set Theory through guided analysis of the Shopee marketplace to demonstrate the application of mathematical concepts in authentic digital environments. Second, each project team selected and analysed a different domestic or international marketplace to identify the

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implementation of Set Theory concepts within platform features and business processes. Third, students employed Generative AI to support the design and development of simplified marketplace applications using HTML, CSS, and JavaScript. Throughout this stage, AI was utilised to facilitate idea generation, interface design, coding assistance, debugging, and iterative refinement while students remained responsible for mathematical modelling and decision-making. Finally, each team presented and demonstrated its application, followed by peer discussion and instructor feedback to evaluate both conceptual understanding and application functionality.

Data were collected from multiple sources to provide a comprehensive evaluation of the proposed learning approach. Quantitative data were obtained through competency-based assessment rubrics that evaluated students' mathematical modelling, application functionality, programming implementation, AI utilisation, and presentation performance. Qualitative data consisted of classroom observations, students' project documentation, reflective learning records, and the

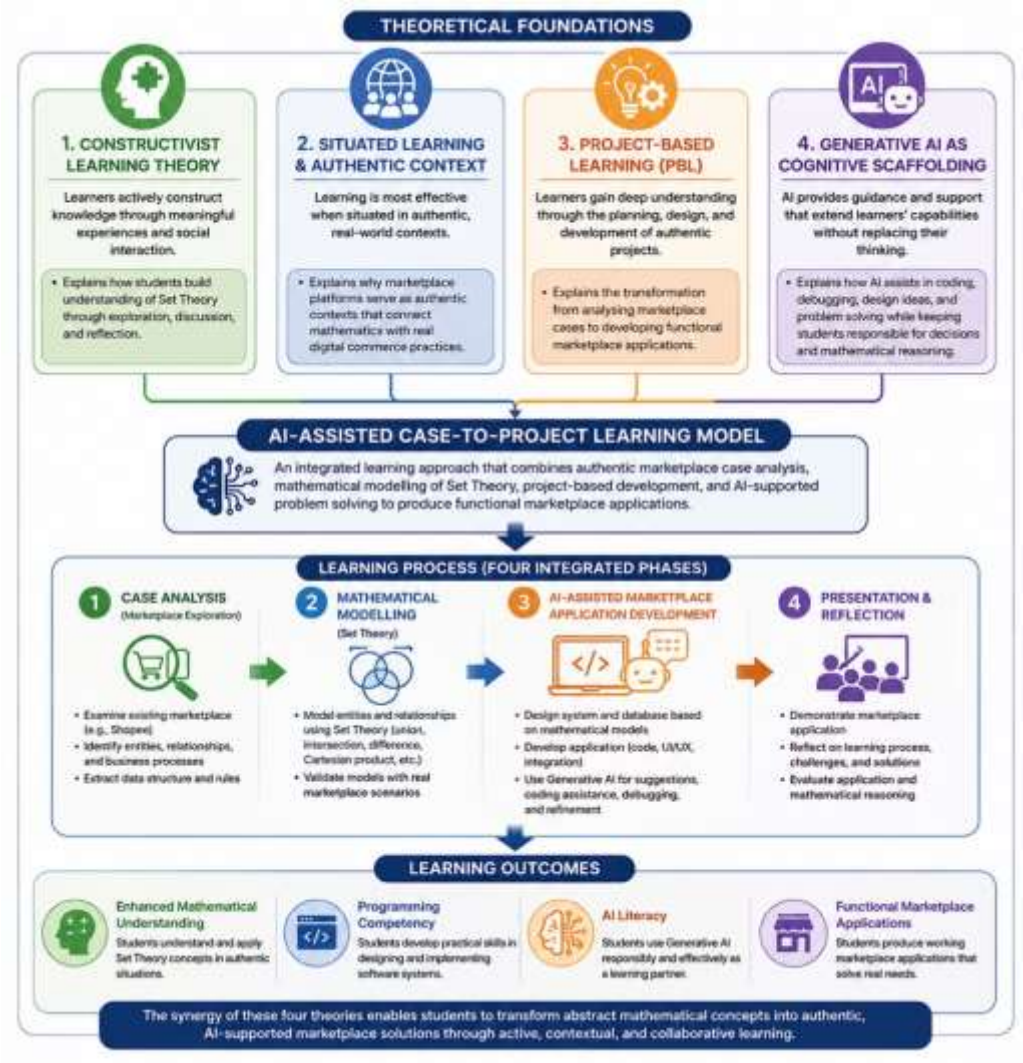

Figure 1. Conceptual Framework

ompleted marketplace applications. Quantitative data were analysed using descriptive statistics, whereas qualitative data were analysed through thematic analysis to identify patterns related to students' conceptual understanding, interdisciplinary learning, and the implementation of Set Theory

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in marketplace application development. The findings from both datasets were subsequently integrated to generate a comprehensive interpretation of the learning outcomes.

C. RESULTS AND DISCUSSION

Implementation of AI-Assisted Case-to-Project Learning

The implementation of the AI-Assisted Case-to-Project Learning approach was successfully completed by all ten student teams throughout the intervention. The learning activities followed four sequential stages, beginning with instructor-guided exploration of Set Theory using the Shopee marketplace as an authentic contextual example. This introductory activity enabled students to recognise that abstract mathematical concepts are embedded in real-world digital platforms before progressing to independent exploration and application.

Following the initial exploration, each student team analysed a different marketplace platform to identify the implementation of Set Theory concepts in product categorisation, search mechanisms, filtering systems, and customer interactions. The findings from this case analysis became the conceptual foundation for developing a simplified marketplace application. During the development process, students utilised Generative AI to support interface design, programming, debugging, and code refinement while independently determining the mathematical structure and application logic. This approach positioned AI as a learning facilitator rather than a replacement for students' analytical and problem-solving abilities.

All project teams successfully developed functional marketplace applications and presented their projects at the end of the learning intervention. The completed applications demonstrated that students were able to transform theoretical concepts into practical software artefacts by integrating mathematical reasoning with programming skills. The four learning stages implemented throughout the intervention are illustrated in Figure 2.

Figure 2. AI-Assissted Case-to-Project Learning Processes

Students' Competency Achievement

To evaluate the effectiveness of the proposed AI-Assisted Case-to-Project Learning approach, students' competencies were assessed using a competency-based rubric at the completion of the

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learning intervention. The assessment focused on five dimensions that reflected the intended learning outcomes of the course, namely mathematical modelling, marketplace application development, programming implementation, AI utilisation, and presentation and collaboration. The assessment results are presented in Table 2.

Table 2. Students' Competency Assessment Results

Competency Dimension	Mean Score	Category
Mathematical Modelling	88.6	Excellent
Marketplace Application Development	90.2	Excellent
Programming Implementation	87.5	Excellent
AI Utilisation	91.8	Excellent
Presentation and Collaboration	89.1	Excellent
Overall Mean	89.7	Excellent

The results indicate that students achieved excellent performance across all competency dimensions, with an overall mean score of 89.4. AI utilisation obtained the highest mean score (91.8), suggesting that students effectively incorporated Generative AI into interface design, programming support, debugging, and code refinement throughout the project. Marketplace application development also demonstrated a high level of achievement, indicating that students successfully translated theoretical concepts into functional digital applications.

Although mathematical modelling obtained the lowest mean score among the assessed dimensions (88.4), it remained within the excellent category. This finding suggests that students were able to identify and apply Set Theory concepts appropriately when analysing marketplace platforms and designing application features. Collectively, these findings demonstrate that the proposed learning approach supported not only programming competence but also students' ability to integrate mathematical reasoning, AI-assisted development, and collaborative problem-solving in an authentic software development context.

The marketplace applications developed by the student teams demonstrated the successful integration of Set Theory concepts into authentic software development. Rather than merely constructing user interfaces, students were required to justify how mathematical concepts informed the design of application features and data organisation. Consequently, the resulting applications represented both functional software products and evidence of conceptual understanding.

Across the ten project teams, students implemented common marketplace features, including product categorisation, search and filtering, shopping cart management, payment options, and delivery services. During project development, Generative AI supported programming activities such as code generation, debugging, and interface refinement. However, the identification and implementation of Set Theory concepts remained the responsibility of the students, ensuring that mathematical reasoning guided the application design rather than being automatically generated by AI.

Table 3 demonstrates that the developed applications extended beyond programming exercises by embedding mathematical structures into real marketplace functionalities. The mapping illustrates how abstract concepts from Set Theory were translated into practical software features commonly found in contemporary e-commerce platforms. This finding supports the premise that contextual case analysis followed by AI-assisted project development can facilitate the transformation of mathematical knowledge into authentic computing applications.

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Table 3. Mapping of Set Theory Concepts to Marketplace Application Features

Set Theory Concept	Marketplace Application Implementation
Set	Product categories (Electronics, Fashion, Books, Food, etc.
Subset	Electronics → Smartphones, Laptops, Accessories
Union	Combined search results from multiple product categories
Intersection	Products satisfying multiple conditions (e.g., Electronics ∩ Discount)
Complement	Products outside the selected category or filter
Cartesian Product	Customer–Product combinations during order processing

Figure 2 presents representative marketplace applications developed by the student teams during the learning intervention. The applications include essential marketplace functionalities, such as user authentication, product catalogues, shopping cart management, and checkout with digital payment options. Although the visual design varied across teams, all applications demonstrated the successful integration of Set Theory concepts into software functionalities through product categorisation, filtering mechanisms, and user-product interactions. These artefacts provide tangible evidence that students were able to transform abstract mathematical concepts into authentic digital solutions while applying programming skills and Generative AI as development support.

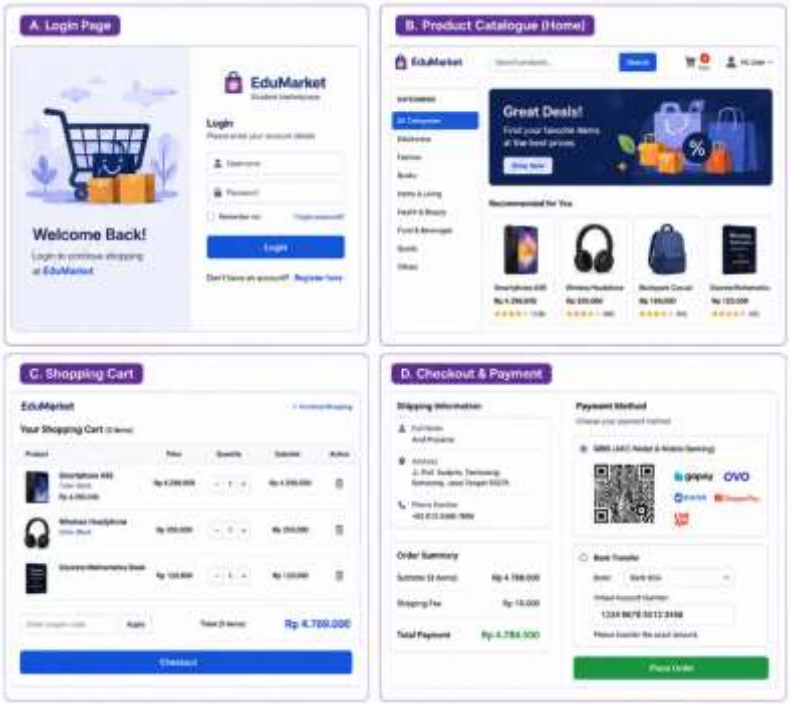

Figure 3. Example of Student Marketplace Application Developed during the Learning Intervention

AI-Assissted Development Process

Qualitative analysis of the project artefacts and AI interaction logs revealed that Generative AI primarily functioned as a development assistant rather than a substitute for students' reasoning. Across the project teams, AI was consistently utilised to generate interface layouts, recommend HTML and CSS structures, provide JavaScript code suggestions, identify programming errors, and assist in debugging. Nevertheless, students independently determined the mathematical modelling of

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marketplace features, including the identification and implementation of Set Theory concepts within the application design.

Analysis of the development logs further indicated an iterative learning process in which students refined AI-generated outputs through repeated prompting, code modification, and testing. Rather than accepting AI responses without evaluation, students compared alternative implementations, revised generated code, and adjusted application logic to ensure consistency with the intended mathematical concepts. This iterative interaction encouraged active problem-solving and strengthened the connection between conceptual understanding and software development.

Table 4 demonstrates that Generative AI supported the technical aspects of application development while students retained responsibility for mathematical reasoning and decision-making. These findings suggest that AI functioned as a cognitive scaffold that facilitated software development without replacing students' conceptual understanding of Set Theory.

Table 4. Typical Use of Generative AI During Marketplace Application Development

Development Activity	**AI Support**	**Student Responsibility**
UI Design	Interface suggestions	Final layout selection
HTML Structure	Code generation	Code modification
CSS Styling	Style recommendations	Visual refinement
JavaScript	Function suggestions	Logic implementation
Debugging	Error detection	Error validation and correction
Set Theory Modelling	Concept explanation	Mathematical modelling and implementation

To complement the quantitative findings and application artefacts, qualitative analysis was conducted using students' AI interaction logs, project documentation, and source code revisions generated throughout the marketplace application development process. These data provided insights into how students interacted with Generative AI and how AI-assisted support influenced the design, programming, and debugging activities without replacing students' mathematical reasoning. Representative examples of AI-supported development activities are presented in Figure 4.

Figure 4 illustrates three representative AI-assisted development activities performed by students during the project, namely interface (UI) design, JavaScript programming, and debugging. The interaction logs indicate that students actively used Generative AI to obtain interface recommendations, generate initial code structures, identify programming errors, and refine application functionality through iterative prompting. Rather than directly adopting AI-generated outputs, students evaluated, modified, and integrated the suggested solutions into their applications according to the project requirements.

These findings suggest that Generative AI functioned primarily as a cognitive scaffold that supported software development while maintaining students' responsibility for mathematical modelling and programming decisions. The iterative interactions recorded in the AI logs demonstrate that students engaged in reflective problem-solving by comparing alternative solutions, validating AI-generated code, and refining application logic to ensure consistency with the implementation of Set Theory concepts. This evidence reinforces the role of AI as a facilitator of authentic learning rather than a substitute for conceptual understanding.

Collectively, the quantitative assessment, application artefacts, and AI interaction logs demonstrate that the proposed AI-Assisted Case-to-Project Learning approach enabled students to progressively transform abstract Set Theory concepts into functional marketplace applications. The learning process moved beyond conceptual understanding by engaging students in analysing

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authentic digital platforms, modelling mathematical relationships, and implementing these concepts through AI-supported software development. This integrated process illustrates how contextual cases

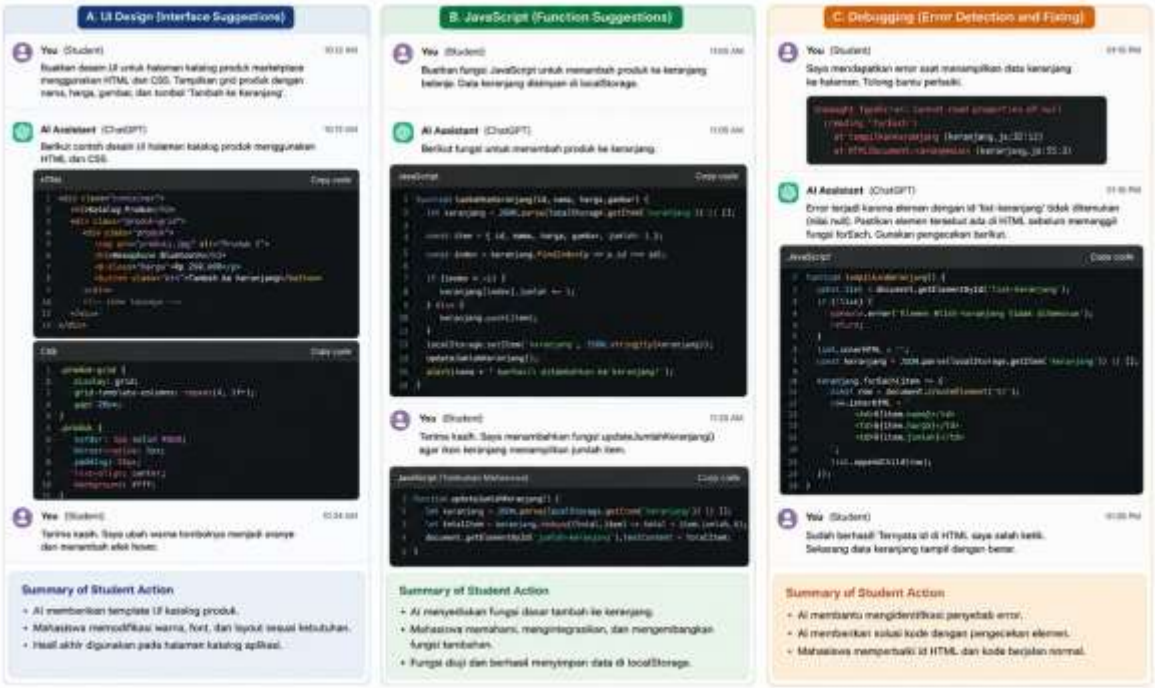

Figure 4. Example of AI Interaction Logs

Discussion

The findings demonstrate that the proposed AI-Assisted Case-to-Project Learning approach effectively supported students in connecting abstract mathematical concepts with authentic software development tasks. Unlike conventional Discrete Mathematics instruction, which often emphasises symbolic manipulation and procedural exercises, the present approach situated Set Theory within the familiar context of digital marketplace platforms before guiding students towards application development. This progression enabled students to move from conceptual understanding to practical implementation, as reflected in their competency achievement and the successful completion of marketplace applications. These findings are consistent with previous studies reporting that contextual and project-based learning enhance students' conceptual understanding and problem-solving abilities, while extending this evidence to the teaching of Set Theory through authentic software development (Kraft and Marco-Almagro, 2022; Haas *et al.*, 2023; Ramirez-Montoya *et al.*, 2024).

Another important finding concerns the role of Generative AI during the software development process. Analysis of AI interaction logs indicates that AI primarily functioned as a cognitive scaffold by assisting students in interface design, programming, debugging, and iterative code refinement. Rather than replacing students' reasoning, AI facilitated technical development while students remained responsible for mathematical modelling and application logic. This finding supports recent studies highlighting the educational potential of Generative AI as a learning partner that enhances productivity and problem-solving (Tang and Guo, 2024; Beldad and Miedema, 2025; Matsunaga and Miyata, 2026). However, the present study further demonstrates that AI can be integrated into

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mathematics education without diminishing students' conceptual engagement, provided that learning activities require learners to justify and implement mathematical ideas independently.

A notable contribution of this study lies in demonstrating how Set Theory can serve as the conceptual foundation for interdisciplinary software development. The mapping between Set Theory concepts and marketplace functionalities illustrates that mathematical structures are directly applicable to product categorisation, filtering mechanisms, customer-product relationships, and other essential e-commerce features. This finding extends previous contextual learning studies by moving beyond the use of real-world examples as teaching illustrations. Instead, contextual cases became the starting point for authentic software development, allowing students to transform mathematical abstraction into functional digital applications (Aboutajedyne, Alj and Aboutajeddine, 2021; Vidalis and Subramanian, 2024; Friesel, 2025).

The proposed learning approach offers practical implications for vocational computing education. By integrating contextual case analysis, project-based software development, and Generative AI support within a single instructional framework, the approach promotes the simultaneous development of mathematical reasoning, programming competence, AI literacy, and collaborative problem-solving. The originality of this study lies not merely in incorporating AI into learning but in designing a learning pathway that systematically transforms abstract Set Theory concepts into authentic marketplace applications. This integrated pedagogical model provides an alternative instructional strategy for bridging mathematics education and software engineering practice in vocational higher education (Malik and Behera, 2024; Zheng, Lee and Zhang, 2025).

Overall, the findings indicate that AI-Assisted Case-to-Project Learning successfully addressed the gap identified in previous studies by connecting contextual mathematical learning with authentic application development. The integration of marketplace case analysis, Generative AI, and collaborative software development enabled students to translate abstract Set Theory concepts into functional digital applications while maintaining mathematical reasoning as the central component of the learning process. These findings contribute to the growing body of research on AI-enhanced mathematics education by proposing a replicable instructional model that bridges mathematical abstraction and real-world software development in vocational higher education.

D. CONCLUSION

This study investigated the implementation of an AI-Assisted Case-to-Project Learning approach in a Discrete Mathematics course and examined how the proposed approach supported students in transforming abstract Set Theory concepts into authentic marketplace applications. The findings demonstrate that integrating contextual marketplace case analysis, collaborative project development, and Generative AI effectively facilitated students' conceptual understanding and software development competencies. The resulting marketplace applications, competency assessment, and AI interaction logs collectively indicate that students were able to translate mathematical concepts into functional digital solutions while maintaining mathematical reasoning as the foundation of application development.

The study contributes to mathematics and computing education by proposing a replicable instructional model that bridges mathematical abstraction and authentic software development through AI-assisted learning. Unlike approaches that employ contextual examples solely to illustrate mathematical concepts, the proposed model extends contextual learning into application development, enabling students to construct functional software grounded in Set Theory. Nevertheless, this study was conducted within a single vocational higher education institution and focused on one topic in Discrete Mathematics. Future studies may evaluate the proposed approach across different institutions, mathematical topics, and programming environments, as well as

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investigate its long-term impact on computational thinking, software engineering competence, and AI literacy.

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Authors Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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