

## AI-based interactive digital game development in social studies learning to enhance students' computational thinking

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### ABSTRACT

Students' computational thinking skills in higher education remain relatively low, particularly in learning contexts that require problem decomposition, abstraction, and systematic problem solving. This condition highlights the need for innovative learning approaches that actively engage students through digital technology. This study aims to develop an Artificial Intelligence (AI)-based interactive digital game project in Social Studies learning to enhance students' computational thinking skills. The study employed a Research and Development (R&D) design involving a preliminary study, conceptual model development, validation, revision, and implementation. The research population consisted of undergraduate students enrolled in Social Studies Education courses at an Indonesian university, from whom 60 were selected using purposive sampling based on their participation in project-based learning activities. Data were collected through questionnaires, observations, and field notes. Qualitative data were analysed using interactive analysis techniques, while quantitative data were examined using Pearson correlation and simple linear regression. The findings reveal that student involvement in AI-based interactive digital game development projects positively influences computational thinking skills, including decomposition, pattern recognition, abstraction, and algorithmic thinking. These results indicate that integrating AI into project-based learning effectively supports the development of essential 21st-century skills.



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## INTRODUCTION

Computational thinking skills are among the key competencies students need to address learning challenges and complex problems in the digital age. However, computational thinking skills in Indonesia are still relatively low. Research shows that student learning outcomes are often below the Minimum Competency Criteria (KKM), especially in computational thinking (Rijal et al., 2021; Jamna et al., 2022). This is reinforced by PISA 2018 data, which shows that Indonesia ranks 73rd out of 78 countries with an average score of 379, far below the global average. The PISA assessment covers six levels of achievement, with levels 4, 5, and 6 measuring higher-level skills. At this level, the test assesses indicators of the ability to identify, reflect, formulate, interpret, evaluate, generalise, and utilise the information in the questions to solve complex problems

(OECD, 2019). These findings indicate that conventional learning approaches have not fully facilitated the optimal development of computational thinking.

The low level of computational thinking skills indicates that conventional learning approaches have not fully enabled students to develop logical and systematic thinking. Therefore, learning innovations are needed to encourage active student engagement and connect learning to real-world contexts through technology. In the digital age, technology has become an integral part of education by creating new learning patterns that are applied from kindergarten to college (Sudarmo et al., 2021; Sudarsana et al., 2019; Rachmawati et al., 2022; Wahyuningtyas et al., 2022). Technological developments, particularly Artificial Intelligence (AI), have opened up enormous opportunities in designing learning environments that are more interactive, adaptive, and student-centred (Sudarmo et al., 2021; Sudarsana et al., 2019). In this context, digital game-based learning has been widely recognised as a practical pedagogical approach for increasing student engagement, motivation, and higher-order thinking skills (Prensky, 2001; Spires, 2015). Several recent studies show that AI-based learning games can personalise the learning experience, provide real-time feedback, and assist students in the problem-solving process through adaptive mechanisms (Clark et al., 2016; Pujowati et al., 2024; Meiliawati et al., 2024).

Most research on AI-based game learning still positions students as users or consumers of learning media. Studies on gamification and digital literacy (Anwar et al., 2018; Mardina & Wacana, 2018) show positive effects on motivation and technological skills, but they have not explicitly examined the development of computational thinking as a structured cognitive process. Similarly, recent AI-based game research tends to focus on learning outcomes and student engagement, rather than on the process of how designing and developing AI-based games can train the main components of computational thinking, namely decomposition, pattern recognition, abstraction, and algorithm design (Lee et al., 2014; Fajri et al., 2019; Susanti & Taufik, 2021). This study aims to fill this gap by placing students in the role of creators through AI-based, interactive digital game development projects in social studies learning. Unlike previous studies that emphasise AI as an instructional tool, this study integrates AI into a project-based learning framework that requires students to identify problems, design game mechanisms, and systematically implement solutions using digital technology. The integration of project-based learning, the TPACK framework, and AI-based game development in this study contributes theoretically to the development of a learning model capable of fostering computational thinking through authentic, technology-based learning experiences.

The novelty of this research lies in the development of an interactive artificial intelligence-based digital game project specifically applied in social studies learning to improve students' computational thinking. This differs from the research by Anwar et al., (2020), which emphasises the use of digital media in learning in general, and Mardina et al., (2018), which focuses on digital literacy. This study introduces a novel approach to integrating AI technology into digital games while also placing students in an active-creator role. Thus, this study makes a new contribution by connecting social studies learning innovation with strengthening computational thinking as a key competency in the digital era. Based on the problem background, the general problem to be studied is how to develop an interactive digital game project using artificial intelligence in social studies learning to improve students' computational thinking.

## METHOD

This study applies a Research and Development (R&D) design adapted from Borg & Gall (1989), a framework widely acknowledged in educational research for its systematic approach to developing and validating innovative products. The R&D approach employed in this study aligns with the four central characteristics outlined by Borg & Gall (1989), namely; 1) the conduct of preliminary studies to identify research findings relevant to the product being developed; 2) the development of a product informed by empirical findings; 3) the implementation of field testing in authentic contexts; and 4) the revision of the product based on identified weaknesses during field

trials. By following these principles, the study ensures that the model being developed is both research-grounded and responsive to practical demands.

The research was undertaken at the Indonesia University of Education, Bandung, Indonesia, over two years, demonstrating both continuity and depth of inquiry. The procedures were streamlined and adapted into four phases; 1) preliminary study, designed to identify the needs, opportunities, and constraints of integrating digital game-based learning in social studies; 2) conceptual model development, where a project design for AI-based interactive digital games was formulated in line with the TPACK framework; 3) validation and revision of the conceptual model, involving expert judgment and iterative refinement; and 4) implementation of the model in classroom practice to examine its effectiveness and feasibility.

The participants of this study were purposively selected, comprising a sample of 60 students from the larger student population of the Indonesia University of Education. The use of purposive sampling underscores the study's focus on recruiting participants directly relevant to the research objectives, particularly for assessing computational thinking skills within a social studies context. Data collection relied on three complementary instruments: questionnaires, observations, and field notes. The questionnaire item format used in developing this research instrument is the Likert summated rating scale measurement tool, which is an item writing format using a scale, where, with this writing format, respondents are asked to indicate their degree of agreement (conformity) and disagreement (nonconformity) with certain statements with five alternative answer choices. The questionnaire was then analysed using correlation/regression analysis (Sugiyono, 2021). Furthermore, the author hopes that this observation technique will enable him to collect data directly and obtain a clearer picture of the implementation of the AI-based Interactive Digital Game Development Project in lectures. Finally, field notes are a complementary tool for determining the effectiveness of interactive digital game development projects based on artificial intelligence in social studies learning to improve students' computational thinking. This triangulation of instruments enhances the credibility and richness of the data, as each instrument captures different dimensions of the research phenomenon: quantitative perceptions through questionnaires, behavioural dynamics through observations, and nuanced contextual details through field notes.

In terms of data analysis, both qualitative and quantitative approaches were employed to provide a comprehensive interpretation of the findings. Qualitative data were analyzed using the interactive model (Fraenkel & Wallen, 1993), which includes five key stages: 1) data reduction to focus on relevant information; 2) systematic categorisation and classification of data; 3) data display for more precise interpretation; 4) cross-site analysis to identify patterns and variations; and 5) drawing conclusions based on emergent insights. This iterative and reflective process strengthens the depth and trustworthiness of the analysis. On the other hand, quantitative data from the questionnaires were analysed using correlation and regression analyses (Creswell, 2018), enabling the study to statistically test relationships among variables, particularly the effects of the developed model on students' computational thinking.

Table 1. Instrument Designed

Variable	Indicator	Questions	Instrument Type
X: Interactive Digital Game Development Project	Interactive Digital Games Creation Project	11	Likert Scale
	Use of Digital Media Elements	5	
	Utilisation of Artificial Intelligence	4	
Y: Computational Thinking Skills	Decomposition	6	Survey of Study Habits and Attitudes
	Pattern Recognition	6	
	Abstraction	6	
	Algorithm	7	

Based on Table 1, there are two variables measured: X, the Interactive Digital Game Development Project and Y, the Computational Thinking Skills. In variable X, the measurement was carried out using a Likert-scale instrument with three indicators: Interactive Digital Games Creation Project (11 questions), Use of Digital Media Elements (5 questions), and Utilisation of Artificial Intelligence (4 questions). Meanwhile, variable Y was measured using the Survey of

Study Habits and Attitudes, with four indicators of computational thinking skills, namely Decomposition (6 questions), Pattern Recognition (6 items), Abstraction (6 items), and Algorithm (7 questions), as shown in Table 2.

Table 2. Validity Test

Variable	Items	Total Range	Sig.	Description
X: Interactive Digital Game Development Project	20	0.554 – 0.838	< 0,01	All Item Valid
Y: Computational Thinking Skills	25	0.482 – 0.793	< 0,01	All Item Valid

Validity testing was conducted by correlating the scores of each statement item (X1–X20) with the total variable. The score was obtained using Pearson Product-Moment correlation. There were 60 respondents in this study, so the table value of  $r$  at a significance level of 5% ( $\alpha = 0.05$ ) with a degree of freedom ( $df = 58$ ) was 0.254. Based on the analysis results, all items from X1 to X20 have a calculated  $r$  value greater than the table  $r$  value (0.254) and a significance value (Sig. 2-tailed) of 0.000. The validity of the instrument on variable Y was tested using Pearson's Product-Moment correlation, which correlated the scores of each statement item (Y1–Y25) with the total variable score (TOTALY). There were 60 respondents in this study, so the table value of  $r$  at a significance level of 5% ( $\alpha = 0.05$ ) was 0.254. Based on the results of the analysis in the Correlations table, it was found that all items of variable Y had correlation coefficients (calculated  $r$ ) greater than the table  $r$ , with a significance value (Sig. 2-tailed) less than 0.05. The item–total correlation values ranged from 0.482 to 0.793, indicating a moderate to strong relationship between each item and the total variable score.

Table 3. Reliability Test

Variable	Cronbach's Alpha	N of Items
X: Interactive Digital Game Development Project	.946	20
Y: Computational Thinking Skills	.952	25

The results of the reliability test in Table 3, using Cronbach's Alpha, yielded a value of 0.946 with 20 items. This value is greater than 0.70, indicating that the research instrument has a very high level of reliability and is suitable for use as a measurement tool in research. The reliability test of the research instrument was conducted using Cronbach's Alpha to determine the internal consistency of the statement items on the Y variable. Based on the Reliability Statistics analysis, a Cronbach's Alpha of 0.952 was obtained with 25 statement items. The Cronbach's Alpha value exceeds the minimum required limit of 0.70, indicating that the research instrument has a very high level of reliability. This means that all statement items in variable Y exhibit good consistency and yield stable measurement results. Therefore, it can be concluded that the instrument for variable Y is highly reliable and suitable for further data analysis in this study.

Overall, the methodological rigour of this study lies in its combination of R&D design principles, purposive sampling, instrument triangulation, and mixed-method analysis. These elements collectively provide a robust foundation for developing, validating, and implementing an AI-based interactive digital game project in social studies learning, while also ensuring that the findings have both theoretical and practical significance.

## RESULTS AND DISCUSSION

### Results

#### *Artificial Intelligence-Based Interactive Digital Game Development Project Model*

This learning model emphasises a contextual approach, namely learning that directly links the material to everyday reality so that it has practical value and meaning for students, both as individuals, members of society, and citizens. The learning process design is structured in line with the characteristics of 21st-century learning, which demand critical thinking and problem-solving skills, creativity and innovation, as well as communication and collaboration. Within this

framework, project-based learning is considered relevant for building social meaning and 21st-century competencies.

Furthermore, this model integrates the TPACK (Technological Pedagogical Content Knowledge) framework as a basis for combining technological, content, and pedagogical strategies in the learning process. This integration is implemented in the Artificial Intelligence-Based Interactive Digital Game Development Project, whose syntax is shown in Figure 1. This project comprises five main stages: project idea and design development, material synchronisation, digital resource utilisation, and product assessment. In practice, these stages represent the concrete application of TPACK integration in project-based learning.

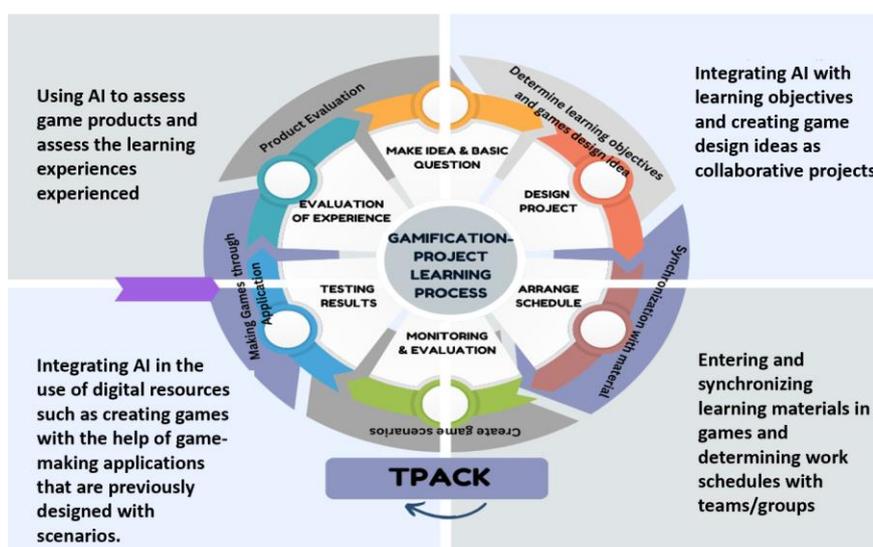


Figure 1. Syntax of the AI-Based Interactive Digital Game Development Project Model

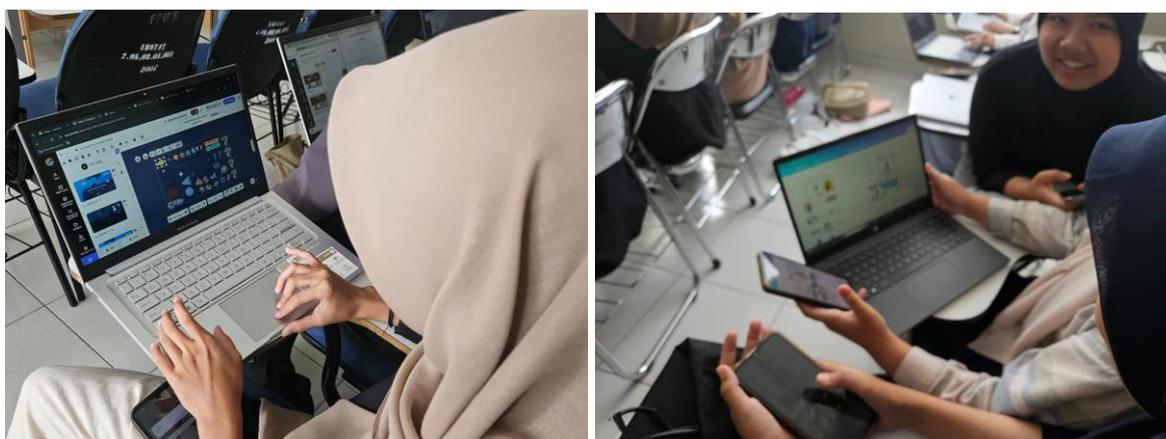
(Source: Author, 2025).

The project structure in Figure 1 for the development of this AI-based interactive digital game is based on the basic principles of project-based learning, which emphasise active engagement, collaboration, and the creation of tangible products. The first principle reflects the conventional stages of project learning, beginning with the formulation of ideas and essential questions that serve as the inquiry driver. The development of project designs follows this: the organisation of team schedules to ensure collaborative efficiency, the evaluation of project outcomes, and, finally, the reflective assessment of learning experiences. Such a structure ensures that learning is not only product-oriented but also process-oriented, thereby fostering both cognitive and metacognitive growth among students.

The second principle delineates the specific stages tailored for AI-based interactive digital game development. These include; a) defining the learning objectives and conceptualizing initial game ideas to ensure alignment with curricular outcomes; b) selecting and refining the central theme or core concept of the game; c) designing a game scenario that integrates pedagogical content with interactive digital elements; d) developing the digital game using appropriate applications and AI-driven tools; and e) evaluating the product through iterative testing and validation processes. This stepwise progression bridges theoretical learning objectives with practical technological implementation, enabling learners to construct knowledge actively through digital creativity.

The learning methods employed within this project are deliberately varied to accommodate different stages of the process and different learning styles. Traditional methods, such as lectures, provide conceptual grounding, while inquiry-based approaches stimulate critical questioning and exploration. Discussions and collaborative teamwork foster communication and collective problem-solving, whereas practical integration and simulations allow students to apply theoretical concepts in technology-assisted contexts. The inclusion of these methods demonstrates a blended learning approach that harmonises pedagogy and technology.

Central to this project is the integration of the TPACK (Technological Pedagogical Content Knowledge) framework, which operationalises the synergy between content, pedagogy, and technology. This integration is evident in several key dimensions; a) the utilization of AI tools to support the formulation of learning objectives and the co-creation of game design ideas, positioning game development as a collaborative learning project; b) the incorporation and synchronization of disciplinary learning materials into game structures, coupled with collaborative planning through team scheduling; c) the integration of ICT resources in game development using AI-based applications that guide scenario building and design implementation; and d) the employment of AI in evaluating both the game product and the learning experience, thereby ensuring a feedback-rich and reflective process—the process of digital game development into social studies learning, as seen in Figure 2.



**Figure 2.** Processing Digital Game Development into Social Studies Learning  
(Source: Author, 2025).

Taken together, these syntactic elements establish a comprehensive model for integrating AI-driven digital game development into social studies education. The approach not only equips students with essential 21st-century competencies such as critical thinking, creativity, collaboration, and digital literacy but also provides them with experiential learning opportunities that connect theoretical knowledge to practical applications in an authentic, technology-enhanced context.

### ***Creating Interactive AI-Based Digital Games through Project Learning***

The process of creating interactive AI-based digital games through a project learning approach consists of the following stages: 1) Students use project learning to come up with ideas for games to be created. The games are created by each individual using materials selected in advance during the inquiry stage; 2) Students identify the learning objectives to be included in the educational games; 3) Each student creates a storyboard for the game, which includes the scenarios to be depicted in the game; 4) Each student explores and uses game maker applications for each desired game criterion; 5) Lecturers monitor and supervise students' work from the beginning to the end of the product development process; 6) Each student presents their product and tests it in front of the class. Other students will respond to each other's products for the assessment process; 7) Lecturers assess students' products and conduct expert validation tests on the content and ease of use.

Figure 2 shows the results of students' work creating interactive games on economic growth in the trade sector, cities and communities, and social interaction, presented through adventure animations in Notebook Island, Halloween, and Froggy Jumps. The games are designed to be engaging, featuring adventure missions that involve solving puzzles to earn rewards in the form of sweets. Each puzzle contains questions about regional conditions in Indonesia. The games consist

of several puzzle levels, ranging from astronomical locations, time zone divisions in Indonesia, weather and climate, and geological conditions. Each question must be answered correctly to accumulate more points, as shown in Figure 3.

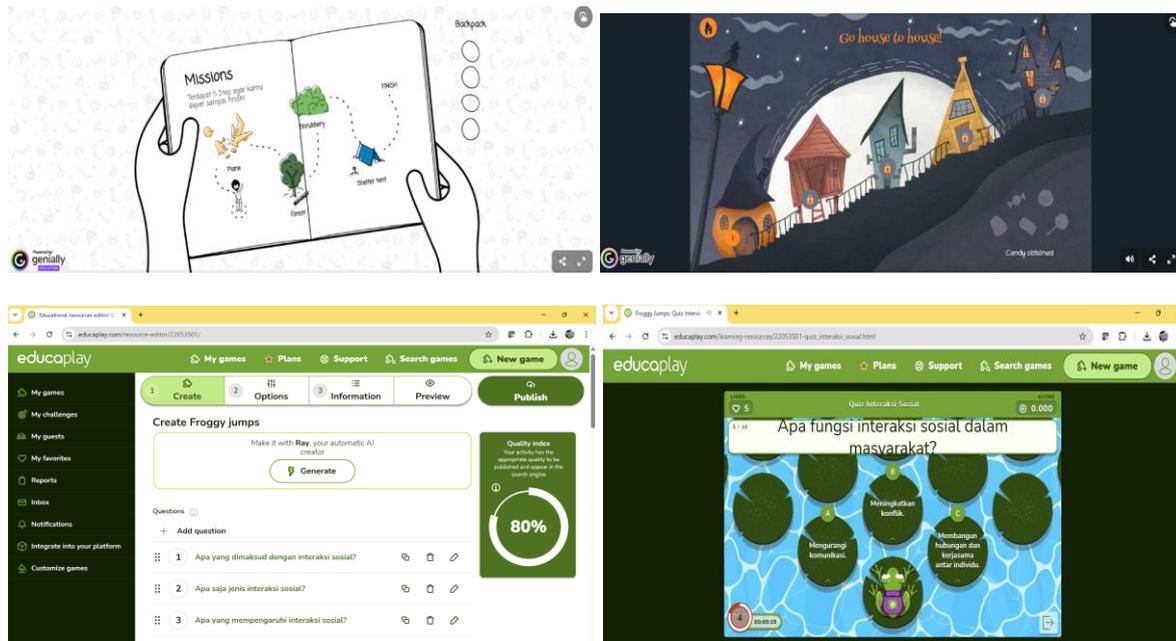


Figure 3. Genially and Educaplay Game Creation Products using AI  
(Source: Author, 2025).

**The Impact of AI-Based Interactive Digital Game Development Projects on Improving Students' Computational Thinking**

The section on seeking influence in a programmed means evaluating the programme, namely the AI-Based Interactive Digital Game Development Project. This learning is carried out in ICT classes to achieve specific objectives that can increase students' computational thinking. Therefore, the concept of effectiveness is needed, which is included in the broader concept of evaluation. The implementation of ICT literacy learning through the AI-Based Interactive Digital Game Development Learning Project can be one of the efforts to support the success of improving students' computational thinking, with the following correlations.

Table 4. Correlation between Learning Projects for Creating Interactive Digital Games Based on AI and Computational Thinking

		(X)	(Y)
Learning Projects for Creating Interactive Digital Games Based on AI	Pearson Correlation	1	.548**
	Sig. (2-tailed)		.000
	N	62	62
Students` Computational Thinking	Pearson Correlation	.548**	1
	Sig. (2-tailed)	.000	
	N	60	60

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The results in Table 4 of the study indicate a significant positive correlation between the Artificial Intelligence (AI)-based Interactive Digital Game Development Project and an increase in students' computational thinking. Based on the correlation analysis, a Pearson correlation of 0.548 was obtained at the 0.001 significance level ( $p < 0.01$ ), indicating a moderate correlation between the two variables. This finding indicates that the more actively students engage in the design,

development, and use of AI-based interactive digital games, the stronger their computational thinking skills will be. Based on the regression test results, the results are as described in [Table 5](#).

**Table 5.** Regression Result

Model	R	R Square	Adjusted R Square
1	.548 <sup>a</sup>	.300	.289

a. Predictors: (Constant), Learning Project

The results of simple regression analysis show that the Artificial Intelligence (AI)-based Interactive Digital Game Development Project has a positive effect on improving students' computational thinking. Based on the regression model summary, an R value of 0.548 was obtained, indicating a positive relationship between the two variables. An R Square value of 0.300 indicates that the AI-based interactive digital game development project explains 30.0% of the variation in students' computational thinking abilities, with the remaining 70.0% influenced by factors outside this research model. Thus, these regression results reinforce the idea that AI-based interactive digital game development projects can be an effective learning strategy for improving students' computational thinking skills. Although its contribution is only 30.0%, the relationship's significant direction indicates that integrating AI into learning projects can be a key supporting factor in developing students' computational thinking competencies in the digital era.

### Discussion

The results of the study indicate that the Interactive Digital Game Development Project, the Use of Digital Media Elements, and the Utilisation of Artificial Intelligence (AI) in social studies learning received a predominantly high response. In interactive digital game development projects, the majority of students stated that their involvement in creating digital media was constructive for understanding social studies material. Collaboration with lecturers, the use of digital platforms such as Genially, Canva, and Educaplay, and the availability of clear guidelines made students more focused on producing innovative learning products aligned with the curriculum. This shows that digital games are designed to be interactive, engaging, and educational, serving as a complement to modern learning media that help students learn basic concepts in a fun way ([Faizatunisa & Kuniati, 2024](#)). The integration of AI technology allows games to tailor learning materials and challenges to students' abilities, creating a more personalised and engaging experience ([Pujowati et al., 2024](#)). AI-supported games and simulations enable students to learn through hands-on practice and interaction with relevant content, making complex concepts easier to understand and apply ([Meiliawati et al., 2024](#)).

Regarding the use of digital media elements, student responses indicate that the AR-based interactive games and other digital media they created included features such as levels, reward systems, usage guides, and attractive, creative designs. The effectiveness of games is influenced by design, playing duration, additional instructions, and the integration of learning mechanics such as feedback and scaffolding ([Clark et al, 2016](#)). The application of digital games in learning creates an attractive system through elements such as points, ranks, levels, leaderboards, gifts, and so on ([Rahardja et al., 2016](#)). This shows that students do not focus solely on content delivery but also on engagement and user experience in the learning process. From the perspective of AI use, students reported significant benefits during the development of learning media. AI was used to customise content, provide recommendations for solutions to project challenges, and make the learning process more efficient, accurate, and structured. The presence of AI not only accelerated the development process but also encouraged students to think strategically in making decisions related to media design. Overall, the results of this analysis show that the AI-based Interactive Digital Games Creation Project contributes positively to improving the quality of project-based social studies learning. The integration of interactive digital games, creative digital media elements, and AI technology can create a collaborative, adaptive, and enjoyable learning environment aligned with students' needs in the digital era.

The results show that Computational Thinking Skills are in the high category, with respondents tending to rate the indicators at the “often” to “always” level. The four main aspects of CT, namely decomposition, pattern recognition, abstraction, and algorithm design, form the basis for analysis and problem solving (Fajri et al., 2019; Susanti & Taufik, 2021). In terms of decomposition, students demonstrated the ability to divide social studies material into smaller sub-topics, making it easier for them to translate it into interactive digital media. They can also identify specific social issues and organise them into simpler project stages to work on. In terms of pattern recognition, students are accustomed to linking their previous media creation experiences to be reused in new projects. They can recognise frequently occurring social studies concepts and compare various social issues to identify patterns of resolution that can be incorporated into games or interactive media. In terms of abstraction, students can select relevant information and filter out unnecessary data. They are also accustomed to simplifying complex social studies material to make it easier to understand, as well as focusing digital media content on the core issues. This ability demonstrates the ability to manage data and information critically to make learning media more effective.

In terms of algorithms, students can design systematic steps for developing digital learning media. They can sequence game flows, create coherent guides, and retest products to ensure they align with learning objectives. In addition, the ability to improve or rearrange stages demonstrates that students have the flexibility to address technical and conceptual obstacles. Overall, variable Y shows that students have good computational thinking skills. This is reflected in their ability to analyse, organise, and solve problems through interactive digital media. Thus, computational thinking is not only a technical skill but also a cognitive strategy that supports the success of project-based learning, especially in the context of developing AI-based interactive digital games. Additionally, CT enhances professionalism and problem-solving sensitivity and encourages innovation in creating more practical and efficient systems. The characteristics of CT include conceptual thinking skills, problem representation through abstraction, automated algorithm design, and a human-centred approach that combines technology with creative thinking skills (Simanjuntak et al., 2023; Aditya, 2018; Anggriani, 2023).

The results of the study indicate a significant positive relationship between the variable Artificial Intelligence-based Interactive Digital Game Development Project and the variable students' computational thinking, with a correlation coefficient of 0.407 and a significance level of 0.001. This shows that the more intensively students are involved in interactive digital game development projects that utilise digital media and AI, the higher their computational thinking skills. The results of simple regression analysis show that the Artificial Intelligence (AI)-based Interactive Digital Game Development Project has a positive effect on improving students' computational thinking. Based on the regression model summary, an R value of 0.548 was obtained, indicating a positive relationship between the two variables. The R Square value of 0.300 indicates that the AI-based interactive digital game development project explains 30.0% of the variation in students' computational thinking abilities, with the remaining 70.0% influenced by factors not included in this research model.

The results of the regression analysis showed an  $R^2$  of 0.30, indicating that 30% of the variation in students' computational thinking skills can be explained by involvement in an interactive digital game development project based on Artificial Intelligence (AI). In the context of educational research, this value is categorised as a moderate effect size. A moderate effect size is important because educational phenomena are generally influenced by many complex variables, including cognitive, affective, social, and environmental factors. An effect size of 0.30 indicates that the AI-assisted project-based learning intervention made a practically meaningful contribution, although not a dominant one. This aligns with the characteristics of educational research, where a single learning model rarely explains the majority of the variance in learning outcomes. Other factors, such as learning motivation, students' digital readiness, initial computational thinking skills, the role of the lecturer, and the learning environment, also influence learning outcomes and explain the remaining 70% of the variance not accounted for in the model. The results of regression and correlation tests indicate that the relationship between AI-based digital game development projects and computational thinking skills is statistically significant. This significance indicates that

the relationship observed did not occur by chance, but rather reflects the real influence of the learning model on students' computational thinking skills.

This moderate effect size also highlights the study's limitations. First, the relatively small  $R^2$  value indicates that the AI-based learning model is not yet capable of capturing the full complexity of students' learning processes. Computational thinking is a high-level skill that develops through iterative processes, long-term experience, and interactions with various learning contexts. It therefore cannot be fully explained by a single learning approach. Second, limitations are also related to the relatively limited number and characteristics of the sample. Third, the implementation of AI technology in learning is highly dependent on digital literacy, resource availability, and the readiness of both lecturers and students. Variations in technology-use skills can influence the effectiveness of learning models and contribute to unexplained variations in outcomes in this study. Overall, the moderate effect size ( $R^2 = 0.30$ ) and strong significance indicate that the AI-based interactive digital game development project is an effective but complementary learning intervention, not the sole determinant of learning success. These findings confirm that integrating AI into project-based learning has significant potential to enhance computational thinking skills. However, it needs to be combined with other pedagogical strategies and further explored through follow-up research with more robust designs and a broader range of variables.

## CONCLUSION

Based on the findings, the Artificial Intelligence-based interactive digital game development project in social studies learning contributed positively and significantly to increasing students' computational thinking abilities. Student involvement as creators in the process of designing, developing, and evaluating learning games has been proven to train key aspects of computational thinking, including decomposition, pattern recognition, abstraction, and algorithm design. These findings confirm that integrating AI into project-based learning not only produces innovative learning products but also strengthens higher-order thinking skills relevant to the demands of the 21st century. However, the results of this study need to be understood in light of several limitations. First, the coefficient of determination indicates that the learning model developed explains only part of the variation in students' computational thinking abilities. In contrast, the remaining variation is influenced by factors not examined in this study. Second, the relatively small sample size and the use of purposive sampling techniques limit the generalizability of the findings to other institutional or disciplinary contexts. Third, the measurement of computational thinking skills, which is partly based on perception instruments, may introduce subjective biases and does not fully reflect students' actual long-term performance. Given these limitations, future research should develop a more comprehensive research design, such as involving a larger and more diverse sample, using a longitudinal approach to observe long-term impacts, and combining performance-based assessment instruments to measure computational thinking more objectively.

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