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Integrating Code.org with Discovery Learning through a Number Lock Project to Enhance Conceptual Understanding

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Abstract

This study is a Research and Development (R&D) study aimed at developing a Code.org-based Number Lock Project learning media integrated with Discovery Learning to support junior high school students' conceptual understanding of abstract science topics. The media was developed using the ADDIE model with 32 eighth-grade students of SMP Negeri 18 Makassar as the research subjects. Data were collected through expert validation, student response questionnaires, and learning achievement tests using a one-group pretest–posttest design. Data analysis was conducted through validity testing using the Gregory formula, practicality analysis using a Likert scale, and effectiveness analysis using the N-Gain test. The results showed that the developed media had a very high validity level with a coefficient of 0.83, a practicality level of 93.55% categorized as very feasible, and an N-Gain score of 0.73 categorized as high. These findings indicate that the integration of coding-based media and Discovery Learning has the potential to support student engagement and conceptual understanding through exploratory and problem-solving activities.

Keywords: *Code.Org; Discovery Learning; Learning Media; Conceptual Understanding; Number Lock Project*

Introduction

The rapid advancement of digital technology in education requires innovative instructional approaches that not only increase student engagement but also foster meaningful conceptual understanding. Conceptual understanding is a fundamental component of science and mathematics education because it enables students to relate concepts, apply knowledge, and solve problems effectively. Students who merely memorize procedures without understanding underlying concepts often struggle when encountering problems in different contexts (Mills et al., 2025; Suters & Suters, 2020). Therefore, learning should be designed to encourage students to construct understanding through active and exploratory experiences.

However, previous studies have shown that students' understanding of scientific concepts remains relatively low, particularly in abstract science topics. This issue is associated with the limited use of interactive instructional media and predominantly teacher-centered instruction. As a result, students often struggle to visualize abstract concepts and actively participate in learning activities (Kalelioğlu, 2015; Barradas et al., 2020). In addition, monotonous instruction with minimal exploratory activities contributes to low learning motivation and engagement (Choi

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& Choi, 2024; Oluk & Çakır, 2021). Preliminary observations at SMP Negeri 18 Makassar revealed that science instruction is still largely dominated by direct explanation and exercise-based activities, while the use of interactive digital learning tools remains limited. Consequently, students face challenges in understanding conceptual relationships and applying concepts in problem-solving situations.

One promising approach to enhancing conceptual learning is computational thinking (CT)-based instruction. CT refers to a systematic problem-solving approach involving decomposition, pattern recognition, abstraction, and algorithmic thinking (Wing, 2006). In science learning, CT enables students to organize information, identify conceptual relationships, and solve problems systematically, thereby facilitating deeper conceptual understanding (Kale et al., 2021; Irawan & Rosjanuardi, 2024). This approach aligns with Piaget's constructivism and Vygotsky's social constructivism, both of which emphasize that knowledge is actively constructed through learning experiences and social interaction. Furthermore, Papert's constructionism theory highlights that learning becomes more meaningful when students are directly involved in creating and exploring digital products.

One digital platform that supports CT-based learning is Code.org, which provides a simple, interactive, and user-friendly block-based programming environment for junior high school students. Through coding activities and interactive simulations, students engage in exploration, experimentation, and iterative problem solving. Previous studies have reported that Code.org can improve computational thinking skills, learning motivation, and student engagement (Kalelioğlu, 2015; Choi, 2022). Nevertheless, most existing studies primarily focus on coding skills and engagement, while research examining its contribution to students' understanding of science concepts remains limited.

To maximize the effectiveness of coding-based learning media in conceptual learning, integration with an appropriate instructional model is necessary. One relevant model is Discovery Learning, which emphasizes concept acquisition through exploration, observation, experimentation, and conclusion drawing (Bruner, 1961). In this study, the stages of Discovery Learning were systematically integrated into the Number Lock Project activities. The stimulation stage was implemented through game-based challenges, the problem statement stage involved identifying patterns and solution clues, while the data collection and data processing stages were conducted through code exploration and solution testing. Furthermore, the verification and generalization stages involved evaluating outcomes and drawing conceptual conclusions. This integration enables students to construct concepts through exploratory and problem-solving activities.

Although numerous studies have investigated Code.org and Discovery Learning, both approaches are generally examined separately. Research on Code.org mainly emphasizes coding skills and computational thinking, whereas studies on Discovery Learning focus more on learning activities and critical thinking skills (Rich et al., 2024; Kale et al., 2023). Studies that specifically integrate coding-based educational games within a Discovery Learning framework to support conceptual understanding in science remain scarce. Moreover, limited research has systematically designed problem-solving-oriented coding activities to help students understand abstract concepts through interactive exploration.

Based on these considerations, there is a need to develop coding-based learning media capable of integrating computational thinking, problem solving, and Discovery Learning into a unified instructional design. Therefore, this study aims to develop a Code.org-based Number Lock Project integrated with Discovery Learning to support junior high school students' conceptual understanding. Unlike previous studies that examined Code.org and Discovery Learning separately, this study integrates coding-based educational games within a Discovery Learning framework to facilitate concept exploration, problem representation, and interactive problem solving. This study also contributes theoretically by strengthening the relationship between computational thinking, coding-based learning, and conceptual understanding in junior high school science education.

Method

This study employed a Research and Development (R&D) approach aimed at developing a Code.org-based learning medium in the form of a Number Lock Project integrated with Discovery Learning to support junior high school students' conceptual understanding. The development process adopted the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic framework for designing, developing, and evaluating instructional products in accordance with students' needs and instructional objectives (Muku et al., 2025; Rakha, 2025).

In the analysis phase, a needs assessment was conducted through preliminary classroom observations and interviews with science teachers at SMP Negeri 18 Makassar. The analysis focused on students' characteristics, learning difficulties related to abstract science concepts, the use of instructional media, and the alignment of learning materials with the Grade VIII curriculum. The findings indicated that students still experienced difficulties in understanding abstract concepts, while interactive digital media were rarely used in science instruction.

The design phase involved developing the media flow, interface layout, learning materials, research instruments, and the integration of Discovery Learning stages into the Number Lock Project activities. A learning scenario was designed to incorporate the stages of stimulation, problem statement, data collection, data processing, verification, and generalization. In addition, a blueprint for the conceptual understanding test and student response questionnaire was developed.

During development, the learning media were created using the Code.org platform. The product took the form of a challenge-based educational game in which students solved conceptual problems to obtain a code or PIN. The media included several main features: (1) an introductory page containing contextual narratives and gameplay instructions, (2) challenge pages consisting of logic- and science-based problems, (3) a code/PIN input system, (4) immediate feedback for correct and incorrect responses, and (5) interactive navigation using block-based coding. The media activities encouraged students to explore concepts independently, identify patterns, test solutions, and draw conceptual conclusions.

The developed product was validated by two expert validators, consisting of one subject-matter expert and one media expert. The product was evaluated in terms of content, design, language, and functionality. The validation instrument employed a four-point Likert scale with the following categories: 1 = inadequate, 2 = fairly feasible, 3 = feasible, and 4 = highly feasible. Validation data were analyzed using Gregory's formula to determine the level of agreement between validators.

The implementation phase involved a limited trial with 32 eighth-grade students at SMP Negeri 18 Makassar who were purposively selected based on moderate academic ability and limited experience with coding-based learning media. The implementation was conducted over three meetings, each lasting 2 × 40 minutes. Students worked in small groups consisting of four to five members to complete the challenges in the Number Lock Project. The science teacher acted as a facilitator by guiding students through prompting questions, group discussions, and conceptual reflection. Discovery Learning was systematically integrated through activities involving challenge exploration, clue identification, solution testing, group discussion, and conceptual conclusion drawing based on gameplay activities. Throughout the learning process, classroom observations were conducted to document student engagement, exploratory activities, group collaboration, and problem-solving skills.

The evaluation phase aimed to assess the quality of the developed media in terms of validity, practicality, and effectiveness. Effectiveness testing employed a one-group pretest–posttest design to measure improvements in students' conceptual understanding after using the learning media. Although this design is widely used in educational research to compare learning outcomes before and after treatment, the absence of a control group may introduce limitations to internal validity, such as testing effects and novelty effects (Pektaş et al., 2025). Nevertheless, the design was considered appropriate for preliminary product evaluation in educational development research.

Research data were collected through validation sheets, questionnaires, learning outcome tests, and classroom observations. This study primarily employed a quantitative approach supported by qualitative findings obtained from classroom observations and students' comments during the learning process. Quantitative data were derived from expert validation results, student response questionnaires, and pretest–posttest scores. Meanwhile, qualitative data were obtained from observations of student engagement, validator comments, and students' responses during media implementation. Non-participant observations were conducted using observation sheets covering discussion participation, media exploration, group collaboration, and problem-solving activities. The trustworthiness of qualitative findings was strengthened through source triangulation involving observational findings, questionnaire results, and students' learning outcomes.

The conceptual understanding test was developed based on indicators related to understanding, applying, and interpreting science concepts. The test consisted of 10 structured essay questions aligned with the C2–C4 cognitive levels of the revised Bloom's Taxonomy. The test blueprint included the following indicators: (1) explaining concepts, (2) identifying relationships among concepts, (3) applying concepts in problem-solving situations, and (4) interpreting phenomena based on scientific concepts. An example of a test item was: "Explain the relationship between pressure and surface area in the use of snowshoes." The instrument was validated by experts, and its reliability was tested using Cronbach's alpha, resulting in a reliability coefficient of 0.82, which was categorized as high.

Prior to the study, permission was obtained from the school, and all participants were informed about the purpose of the research. Media validity analysis was conducted using Gregory's formula.

$$V = \frac{D}{A + B + C + D}$$

Where:

- V= Gregory validity coefficient
- A= both validators rated the item as irrelevant
- $B$and C= disagreement between the validators
- D= both validators rated the item as relevant

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The interpretation of validity followed the criteria proposed by Sugiyono (2019): highly valid (0.80–1.00), valid (0.60–0.79), moderately valid (0.40–0.59), less valid (0.20–0.39), and invalid (0.00–0.19).

Student response data were analyzed using the Likert-scale percentage formula:

$$P = \frac{f}{N} \times 100\%$$

Where:

- P= response percentage
- f= total score obtained
- N= maximum possible score

The interpretation of practicality percentages referred to the criteria proposed by Riduwan (2015): highly feasible (81–100%), feasible (61–80%), moderately feasible (41–60%), less feasible (21–40%), and not feasible (0–20%).

The effectiveness of the learning media was analyzed using the Normalized Gain (N-Gain) formula:

$$g = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}$$

The improvement criteria followed Hake's (1999) classification: high ($g > 0.7$), moderate ($0.3 < gleq0.7$), and low ($gleq0.3$). In addition to the N-Gain analysis, a Shapiro–Wilk normality test and a paired-sample t-test were conducted at a significance level of 0.05 to determine the significance of improvements in students' learning outcomes following the implementation of the learning media. This study received official permission from SMP Negeri 18 Makassar prior to implementation. Before the study was conducted, both students and teachers were informed about the objectives and procedures of the research. All participant data were kept confidential and used solely for research purposes.

Result

The Number Lock Project is a game-based learning medium developed using Code.org to enhance problem-solving skills through activities that require students to discover a code or PIN by solving science concept challenges. The media was designed as a challenge-based educational game integrating exploratory activities, pattern identification, solution testing, and conceptual conclusion drawing. The media consists of three main sections: (1) an introductory page containing contextual narratives and gameplay instructions, (2) a main challenge page featuring logic- and science concept-based problems, and (3) a feedback page providing immediate responses to students' answers.

Figure 2. *Presents The Introductory Page, Main Challenge Page, Correct-Answer Feedback Page, And Incorrect-Answer Feedback Page Of The Number Lock Project.*

Classroom observations during the implementation revealed that the interactive and game-based nature of the media, combined with immediate feedback, encouraged greater student participation throughout the learning process. Students actively engaged in group discussions, explored multiple solution alternatives, and tested various strategies before entering the correct code or PIN. In addition, they demonstrated a high level of curiosity during the learning activities. One student commented that “the media made learning more interesting because the questions were presented like a game, so the lesson was not boring.” Another student stated that “the clues and immediate feedback helped identify mistakes quickly.”

These observations suggest that the media effectively promoted active engagement in exploratory and problem-solving activities. The developed media was systematically integrated with the stages of Discovery Learning. The stimulation stage was implemented through game-based challenges designed to trigger students’ curiosity and initial cognitive conflict. During the problem statement stage, students identified patterns and solution clues, while the data collection and data processing stages involved exploration and solution testing within the game environment. The verification and generalization stages were conducted through group discussions and conceptual reflection based on the challenge outcomes. This integration enabled students to construct conceptual understanding through exploratory and collaborative problem-solving activities. The findings indicate that the Code.org-based Number Lock Project integrated with Discovery Learning demonstrated high levels of validity, usability, and effectiveness in supporting students’ conceptual understanding.

Media Validity

The media was validated by two expert validators consisting of a subject-matter expert and a media expert. The evaluation covered content, visual design, language, and media functionality. Table 1 presents the results of media validation using Gregory’s formula.

Table 1*. Media Validation Results Using Gregory’s Formula*

Category	**Validator 1 Weak**	**Validator 1 Strong**	**Total**
Validator 2 Weak	A = 0	B = 1	1
Validator 2 Strong	C = 1	D = 10	11
Total	**1**	**11**	**12**

Table 1 presents the results of the expert validation using Gregory’s formula. The cross-tabulation shows that 10 out of 12 assessment items were classified as strong agreement by both validators (cell D), while only one item was categorized as weak–strong (cell B) and one item as strong–weak (cell C). No items were rated as weak by both validators (cell A = 0). Based on Gregory’s formula, the content validity coefficient was 0.83 $(D/(A+B+C+D)=10/12)$, indicating that the developed learning media has high content validity and is appropriate for use in the learning process after minor revisions based on the validators’ suggestions.

$$V_c = \frac{10}{0+1+1+10} = \frac{10}{12} = 0.83$$

The validity analysis yielded a Gregory coefficient of 0.83, which falls within the highly valid category based on Sugiyono’s (2019) criteria. This result demonstrates that the media achieved strong alignment in terms of content, visual design, language, and functionality. The visual design and functionality aspects received the highest ratings because the media was considered interactive and user-friendly, whereas the language aspect received several recommendations regarding the simplification of gameplay instructions. The validators also suggested improving interface color contrast and simplifying the game instructions to enhance clarity for students.

Based on these recommendations, revisions were made to the visual design and user instructions prior to classroom implementation.

Media Usability

Media usability was evaluated through student response questionnaires covering ease of use, visual appearance, usefulness, and learning engagement. The analysis revealed an average percentage score of 93.55%, which falls within the highly feasible category based on Riduwan's (2015) criteria.

Table 2. *Media Usability Results*

Assessment Aspect	Percentage (%)	Category
Ease of use	94.21	Highly Feasible
Media appearance	92.84	Highly Feasible
Usefulness	93.75	Highly Feasible
Learning engagement	93.42	Highly Feasible
Average	93.55	Highly Feasible

These results demonstrate that the media was easy to use and effectively promoted student engagement during learning activities. The ease-of-use aspect obtained the highest percentage because participants were able to operate the media without significant difficulties. In addition, students actively participated in discussions and explored multiple answer alternatives while completing the game challenges. Classroom observations further revealed that the immediate feedback feature enabled students to identify mistakes instantly, encouraging them to evaluate and revise their answers independently. This pattern highlights the potential of immediate feedback to foster self-correction and reflective learning during game-based activities.

Media Effectiveness

The effectiveness of the media was evaluated based on students' pretest and posttest conceptual understanding scores. The analysis showed an increase in the mean score from 48.75 on the pretest to 85.63 on the posttest. The average N-Gain score was 0.73, which falls within the high category according to Hake's (1999) classification.

Table 3. *Students' Learning Outcome Data*

Component	Score
Mean pretest score	48.75
Mean posttest score	85.63
Pretest standard deviation	18.42
Posttest standard deviation	8.37
Mean N-Gain	0.73
Category	**High**

In addition to the N-Gain analysis, a Shapiro–Wilk normality test and a paired-sample t-test were conducted. The normality test results indicated that both pretest and posttest scores were normally distributed, with significance values of 0.087 and 0.094, respectively ($p > 0.05$). Furthermore, the paired-sample t-test revealed a statistically significant difference between students' pretest and posttest scores following the implementation of the learning media, $t(31) = 12.45, p < 0.001$.

To determine the magnitude of the intervention effect, an effect size analysis was conducted using Cohen's d. The analysis yielded a Cohen's $d$value of 1.84, indicating a large effect size. This result suggests that the learning media had a substantial impact on improving students' conceptual understanding. Improvements were observed across all indicators of conceptual understanding, including concept comprehension, concept application, and scientific

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interpretation. The greatest improvement occurred in the concept application indicator, suggesting that challenge-based problem-solving activities were particularly effective in facilitating the transfer of conceptual knowledge into applied contexts. During the learning process, students not only completed the game challenges but also discussed solution strategies and connected scientific concepts to situations presented in the game environment.

Observation findings further revealed that students tended to test multiple strategies before determining their final answers. Some groups were also observed comparing alternative solutions and explaining the rationale behind their selected answers. These activities reflected students' logical, exploratory, evaluative, and collaborative thinking throughout the learning process. Overall, the findings suggest that the Code.org-based Number Lock Project integrated with Discovery Learning demonstrates strong potential for enhancing junior high school students' conceptual understanding through interactive exploration and problem-solving activities.

Discussion

The findings of this study demonstrate that the Code.org-based learning media integrated with Discovery Learning effectively enhanced students' conceptual understanding. These results suggest that integrating digital technology with active learning approaches can foster more exploratory, interactive, and meaningful learning experiences. In this study, improvements in conceptual understanding were influenced not only by the use of technology itself but also by exploratory activities, problem-solving processes, cognitive engagement, and reflective learning experiences. Previous studies have similarly shown that Code.org supports coding-based learning activities while increasing student engagement and participation during classroom instruction (Maulana, 2025; Astuti et al., 2024).

From the validity perspective, the high Gregory coefficient indicates strong alignment among content, visual design, language, and media functionality with the intended instructional objectives. High validity is essential in educational development research because it reflects the extent to which a product corresponds to instructional needs and students' characteristics (Gregory, 2015; Sugiyono, 2013). Furthermore, the strong validity score suggests that the integration of gameplay activities and science concepts within the Number Lock Project was systematically designed to support students in developing more structured conceptual representations. Similar findings indicate that interactive learning media designed according to students' characteristics can more effectively facilitate conceptual understanding (Verdiatmoko & Pinandita, 2025).

From the usability perspective, the high level of positive student responses indicates that interactive game-based media effectively promoted student engagement. During implementation, participants actively engaged in discussions, explored multiple answer alternatives, and tested various solutions before determining the correct code or PIN. These activities demonstrate that the media functioned not merely as a visual aid but also as a tool for fostering cognitive engagement during learning. Previous studies have likewise reported that game-based learning increases students' interest, engagement, classroom participation, and learning motivation through interactive digital environments (Juliani et al., 2025; Lova, 2021).

Student engagement in this study was strongly influenced by the challenge-based characteristics of the Number Lock Project. The code/PIN-searching challenges encouraged participants to continuously test, evaluate, and revise their problem-solving strategies. This pattern suggests that challenge-based digital environments may stimulate reflective and evaluative thinking processes, which are fundamental components of problem-solving-oriented learning. Moreover, the immediate feedback feature enabled participants to recognize mistakes instantly and independently revise their responses. From a cognitive perspective, immediate feedback promotes self-correction, strengthens self-regulation, and enhances metacognitive awareness during learning activities. Similar findings indicate that coding and problem-solving activities can effectively enhance students' engagement in computational thinking processes (Darmayanti et al., 2023).

Nevertheless, the high level of positive student responses should be interpreted cautiously because it may have been influenced by the novelty effect, referring to students' initial interest in the use of new technology during learning. In addition, the possibility of social desirability bias, in which participants tend to provide favorable responses toward newly implemented instructional media, should also be considered. Therefore, the effectiveness of the developed media should be further examined through long-term implementation and more rigorous experimental studies involving control groups to obtain stronger evidence regarding its educational effectiveness.

From the effectiveness perspective, the high N-Gain score indicates a substantial improvement in students' conceptual understanding following the implementation of the learning media. The paired-sample t-test revealed a statistically significant difference between pretest and posttest scores, while the large effect size demonstrated that the intervention had a strong impact on learning outcomes. N-Gain analysis is widely employed in educational research to evaluate proportional improvements in learning outcomes following instructional interventions (Arikunto, 2009; Oktavia et al., 2019). These findings suggest that the learning activities embedded within the Number Lock Project effectively promoted students' cognitive engagement during the learning process. The improvement in conceptual understanding can be explained through the exploratory and problem-solving activities embedded within the media.

During gameplay, participants not only answered questions but also identified patterns, analyzed clues, tested alternative solutions, and evaluated outcomes. These activities reflect essential components of computational thinking, including decomposition, pattern recognition, abstraction, and systematic problem-solving. Computational thinking has been widely recognized as an important approach for helping students understand scientific concepts through inquiry and problem-solving activities. Likewise, Code.org-based learning environments have been shown to improve students' computational thinking and problem-solving abilities while strengthening conceptual understanding (Izzah et al., 2023; Syaputri et al., 2025; Permatasari et al., 2026).

From a computational thinking perspective, abstraction enables learners to simplify complex information into more manageable conceptual representations, while pattern recognition helps them identify meaningful relationships among concepts during problem solving. Furthermore, systematic solution planning supports the development of logical reasoning in understanding scientific concepts. Thus, coding-based learning contributes not only to the acquisition of technical programming skills but also to conceptual restructuring through exploratory and reflective learning experiences. The integration of coding-based games and Discovery Learning demonstrated how computational thinking-oriented activities can bridge procedural engagement and conceptual reasoning. Participants were not merely engaged in completing game tasks but also developed conceptual understanding through pattern identification, solution testing, and reflective evaluation.

This interpretation is consistent with the view that computational thinking represents a transferable problem-solving approach applicable across diverse educational contexts (Wing, 2006). The integration of Discovery Learning further enabled participants to construct knowledge through direct learning experiences. During the stimulation stage, students encountered game-based challenges that triggered curiosity and cognitive conflict. This conflict encouraged them to question their prior understanding and explore conceptual relationships to solve the challenges.

Subsequently, the problem statement and data collection stages encouraged participants to identify clues and explore alternative solutions. During the verification and generalization stages, participants discussed findings and drew conceptual conclusions based on their exploratory experiences. These processes indicate that learning was not solely directed toward obtaining correct answers but also toward conceptual restructuring throughout the learning process. Similar findings have demonstrated that Discovery Learning effectively enhances critical thinking, learning motivation, and conceptual understanding by encouraging students to construct knowledge independently through exploration and discovery (Dwiyanti et al., 2025; Tamsir et al., 2025; Simanjuntak et al., 2025; Sudarsono & Mawaddah, 2025).

Observation findings further revealed that participants frequently tested multiple strategies before determining their final answers. Several groups were also observed comparing alternative solutions and explaining the rationale behind their selected responses. These activities reflected logical, evaluative, and collaborative thinking processes throughout the learning activities. From a constructivist perspective, such exploratory processes support conceptual assimilation and accommodation through direct learning experiences. Likewise, from Vygotsky's social constructivist perspective, group discussions and social interaction functioned as scaffolding mechanisms that supported conceptual development through peer collaboration and teacher guidance. Collaborative interaction enabled participants to exchange ideas, provide feedback, and develop problem-solving strategies within the Zone of Proximal Development (ZPD).

Compared with previous studies, the primary contribution of this research lies in integrating coding-based game media and Discovery Learning within a unified instructional framework. Previous research has generally focused either on improving coding skills or increasing student engagement through digital media. In contrast, this study demonstrates that the systematic integration of coding activities, problem solving, immediate feedback, and Discovery Learning can effectively support students' conceptual understanding of science. Therefore, this study contributes theoretically to the growing literature on computational thinking-based learning by emphasizing conceptual understanding in addition to technical programming competencies through exploratory, collaborative, and problem-solving activities.

Despite these contributions, this study has several limitations. The relatively small sample size and the use of a one-group pretest–posttest design without a control group limit the generalizability of the findings. Furthermore, the relatively short implementation period prevented the study from examining the long-term effectiveness of the developed learning media. Factors such as technological readiness, students' digital literacy, and the availability of instructional devices may also influence implementation outcomes across different educational contexts. Similar implementation challenges concerning infrastructure readiness and digital competence have also been identified in previous studies on coding-based learning (Nur & Nurhafidzah, 2025).

Therefore, future studies are recommended to employ experimental or quasi-experimental designs involving control groups, larger sample sizes, and longer implementation periods to obtain more comprehensive evidence regarding the effectiveness of the media. Future research may also explore the integration of coding-based learning media with adaptive learning systems, learning analytics, and artificial intelligence to support more personalized and interactive learning experiences. Furthermore, additional studies should investigate how computational thinking and problem-solving skills developed through coding-based learning can be transferred to broader educational contexts beyond digital game-based activities.

Overall, the findings suggest that integrating Code.org-based game environments with Discovery Learning provides a promising pathway for supporting active learning, enhancing student engagement, and strengthening conceptual understanding through interactive exploration and problem-solving activities. These findings also imply that science teachers should systematically integrate digital technology, exploratory learning strategies, and coding-based problem-solving activities to create more interactive, contextual, student-centered, and computational thinking-oriented learning environments suitable for twenty-first-century education.

Conclution

This study successfully developed a Code.org-based Number Lock Project integrated with the Discovery Learning model to support junior high school students' understanding of abstract science concepts. The findings indicate that the developed learning media achieved high levels of validity, usability, and effectiveness in facilitating conceptual learning. By combining computational thinking activities, challenge-based interactions, immediate feedback, and the stages of Discovery Learning, the media promoted active student engagement in exploration, discussion, and problem-solving. These learning experiences enabled students to construct scientific concepts more meaningfully while fostering logical reasoning, collaboration, and reflective thinking. The results further demonstrate that coding-based learning extends beyond developing technical programming skills by serving as an instructional approach that strengthens conceptual understanding through inquiry-oriented and student-centered learning experiences.

This study contributes to the growing body of research on computational thinking by demonstrating that integrating coding-based games with Discovery Learning can effectively bridge digital competencies and science concept mastery. The findings suggest that Code.org-based learning media can serve as an alternative instructional strategy for promoting active, contextual, and interactive science learning in the digital era. Nevertheless, the findings should be interpreted with caution due to the small-scale implementation, the absence of a control group, and the relatively short intervention period, which limit conclusions regarding long-term effectiveness. Future research is recommended to employ more rigorous experimental designs, investigate long-term learning outcomes, and integrate adaptive learning systems, learning analytics, and artificial intelligence to develop more personalized coding-based learning environments and examine the transferability of computational thinking and problem-solving skills across broader educational contexts.

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