

Equations Dash: Interactive Learning Media to Improve Mathematical Problem-Solving Skills

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Abstract: Students frequently encounter difficulties in solving mathematical problems involving one-variable linear equations because limited interactive learning media often support classroom instruction. This study aimed to develop Equations Dash, a Scratch-based interactive learning medium, and evaluate its validity, practicality, and effectiveness in supporting students' mathematical problem-solving skills. The study employed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. Product effectiveness was evaluated using a One Group Pretest–Posttest Design. Participants included one material expert, one media expert, 17 undergraduate students in Mathematics Education for the User Acceptance Test (UAT), and 28 seventh-grade junior high school students for the field implementation. Data were collected through expert validation sheets, UAT questionnaires, mathematical problem-solving tests, and interviews. The interview data were used to complement the quantitative findings by providing deeper insights into students' learning experiences while using the developed media. The data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, the Wilcoxon Signed-Rank Test, and the Normalized Gain (N-Gain) index. The validation results showed that Equations Dash achieved validity scores of 85% from the material expert and 89% from the media expert, indicating that the media was highly feasible after revision. The UAT result reached 87.75%, indicating very high user acceptance. Students' average mathematical problem-solving score increased from 33.75 on the pretest to 96.75 on the posttest. The Wilcoxon Signed-Rank Test indicated a significant difference between the pretest and posttest ($p < 0.001$), while the N-Gain score of 0.95 indicated a high level of improvement. These findings suggest that Equations Dash has strong potential to support students' mathematical problem-solving skills in a blended learning environment. However, because the effectiveness evaluation used a One-Group Pretest–Posttest Design without a control group, interpret the findings cautiously and consider further studies using controlled experimental designs.

Keywords: learning media, ADDIE, mathematical problem-solving skills, junior high school/MTs students.

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■ INTRODUCTION

Learning media has become the backbone of educational innovation, shifting from conventional aids to an immersive, interactive learning environment (Riyat et al., 2025; Srikanth Reddy et al., 2024; Yadav, 2025). Digital media has been shown to increase students' motivation and active engagement and to help visualize

abstract concepts, making them more concrete and accessible (Chang, 2021; Safitri et al., 2022; Shtayyat & Gawanmeh, 2025; Zhou & Yang, 2024). In mathematics, interactive media offers strong potential to create learning experiences that are not only educational but also fun, which are urgently needed to achieve complex learning objectives (Masamah & Murtiyasa, 2025;

Susilawati et al., 2018; Talpur et al., 2024; Widiatsih et al., 2020).

One of the most complex and vital goals of mathematics learning is improving mathematical problem-solving skills, which are core 21st-century competencies and the foundation for logical reasoning (Ndiung et al., 2021; Torres-Peña et al., 2025; Yesseikyzy et al., 2025; Zamnah, 2021). In the grade VII mathematics curriculum, mathematical problem-solving skills are crucial in the One-Variable Linear Equations material (Riyadi et al., 2019). This material requires students to translate contextual problems into algebraic models, a critical stage in mathematical problem-solving (Aguiar et al., 2024; Putra et al., 2018; Reinke, 2019; Soneira et al., 2023). The main difficulty often lies in the modeling and interpretation phases, which indicates the need for strategies and learning tools that bridge conceptual and procedural understanding (Marchisio et al., 2021; Naamaoui

et al., 2024; Plothová et al., 2017; Vidad & Quimbo, 2021).

Although mathematical problem-solving skills are crucial, empirical data, including results from implemented pre-tests, show that student achievement in PLSV material remains relatively low (Ming et al., 2023; Santoso et al., 2019; Wati & Fitriana, 2018). Student learning completeness was determined based on the school's Minimum Completeness Criteria, which was set at a score of 75. Students who scored 75 or higher were categorized as achieving learning completeness, while those scoring below 75 were categorized as not yet achieving learning completeness. The greatest difficulty was observed in the indicators of understanding the problem, devising a plan, carrying out the plan, and looking back, as proposed by (Pólya, 1945), which indicated a lack of familiarity with the Pólya problem-solving flow (Fahrudin & Pramudya, 2019; Fitriani et al., 2022; Mwei, 2017).

Table 1. Preliminary diagnostic test results of students' mathematical problem-solving skills

Indicator	Result
Number of students	28
Mean pretest score	54.3
Students achieving the school's minimum completeness criteria	21% (6 students)
Students below the school's minimum completeness criteria	79% (22 students)

Note: The school's Minimum Completeness Criteria (KKM) was set at 75. Students with scores ≥ 75 were classified as complete, whereas students with scores < 75 were classified as incomplete

Based on the data in Table 1, preliminary diagnostic test results revealed that students' mathematical problem-solving skills were still relatively low. Among the 28 participating students, only 6 students (21%) achieved the school's minimum completeness criteria, while the remaining 22 students (79%) scored below the expected standard. Furthermore, the mean pretest score was only 54.3, indicating that most students had not yet demonstrated adequate mathematical problem-solving skills. These findings confirm a learning problem in the research setting and highlight the need for an innovative learning medium that can facilitate students' conceptual

understanding and improve their mathematical problem-solving abilities more effectively.

This low mathematical problem-solving ability is influenced by limitations in learning media that do not explicitly and interactively support every step of problem-solving (Amir et al., 2018a; Herdianto & Indriati, 2020; Pujiastuti & Pambudi, 2025; Zhou & Yang, 2024). Media used in schools tends to be passive or focuses only on calculation drills (Torralba & Doo, 2020; Yesmambetova, 2019).

Responding to the need for media that is able to visualize abstract concepts while practicing mathematical problem-solving skills,

this study proposes a solution in the form of the development of a game-based interactive media called Equations Dash. The media was developed using the Scratch platform. This visual programming environment has proven to be easy to understand, allowing students to build conceptual understanding through dynamic algebraic visualization, as well as being effective in improving motivation and computational thinking (Chen et al., 2024; Dayron et al., 2025; Leow & Huang, 2021; Li et al., 2021; Yang et al., 2025). With an interactive game base, Equations Dash is designed to guide students through the four stages of mathematical problem-solving in an explicit and engaging way.

From a constructivist learning perspective, interactive learning media enable students to construct knowledge through active exploration, experimentation, and reflection on their learning experiences (Chikurteva et al., 2025). Rather than merely presenting instructional content, effective digital learning media should facilitate the cognitive processes involved in mathematical problem solving. In Equations Dash, each game feature was intentionally designed to support a specific stage of Pólya’s problem-solving process (Pólya, 1945). The relationship between the main features of the developed media and the corresponding stages of mathematical problem solving is presented in Table 2.

Table 2. Relationship between the features of equations dash and the stages of mathematical problem solving

Equations Dash Feature	Supported Cognitive Process	Polya's Problem-Solving Stage
Story-based problems	Understanding the problem context and identifying relevant information	Understanding the Problem
Progressive levels	Planning appropriate solution strategies through gradually increasing levels of difficulty	Devising a Plan
Interactive exercises	Applying mathematical concepts and executing the selected solution strategy	Carrying Out the Plan
Immediate feedback	Evaluating solution accuracy and revising errors through self-reflection	Looking Back

As shown in Table 2, the design of Equations Dash extends beyond providing an engaging digital learning environment by intentionally supporting each stage of mathematical problem-solving. Story-based problems encourage students to identify known and unknown information before solving. Progressive levels guide students to select and refine appropriate solution strategies through increasingly complex challenges. Interactive exercises give students opportunities to apply mathematical concepts and execute planned strategies, while immediate feedback enables them to evaluate their solutions, identify mistakes, and revise their reasoning (Cameron, 2025;

Lähteenmäki et al., 2024). Therefore, improvements in students’ mathematical problem-solving skills can be attributed not only to interactive digital media but also to the explicit integration of cognitive processes aligned with Polya’s problem-solving stages (Fitria et al., 2025; Utaminingsih et al., 2024). Various studies have examined the effectiveness of interactive media and game-based learning in mathematics, starting from the use of Android-based applications (Hidayat et al., 2023; Wahid et al., 2020), PhET simulations (Diab et al., 2024; Medeiros et al., 2024), to RPG-based educational games (Anagnostopoulou, 2024; S. Sari et al., 2024). The results consistently show

that technology integration can improve learning outcomes and mathematical problem-solving skills in general (Al-Hassan et al., 2025a; Ke et al., 2024). However, many of these studies employed platforms or development environments that require advanced programming skills, paid software licenses, or complex deployment procedures, making them less accessible for teachers with limited technical backgrounds. In contrast, Scratch provides a visual, block-based programming environment that lets educators develop interactive learning media without extensive programming knowledge. Furthermore, Scratch supports multimedia integration, immediate visual feedback, and game-based interaction, making it particularly suitable for developing learning media on one-variable linear equations, where students need to visualize algebraic concepts and receive continuous feedback during problem-solving activities (Marini et al., 2026; Strijbol et al., 2024; Wang et al., 2025).

Based on problem analysis and literature review, the novelty of this research lies in the development of the Equations Dash media, which explicitly models and trains students on four indicators of mathematical problem-solving skills (understanding, planning, doing, re-checking) through a Scratch-based game mechanism (Calder, 2018; Chiang & Qin, 2018; Gökçe & Yenmez, 2023). This integrated design guarantees that students not only perform calculations but also build structural thinking when solving single-variable linear equation problems (Çakýrođlu & Muđtuođlu, 2025; Chiang & Qin, 2018).

To address this gap, this study aims to develop the “Equations Dash” interactive learning media using Scratch, evaluate its validity and practicality, and examine its effectiveness in improving students’ mathematical problem-solving skills in one-variable linear equations.

METHOD

Research Design

This study used a Research and Development (R&D) approach based on the ADDIE instructional design model, which consists of the Analysis, Design, Development, Implementation, and Evaluation stages. The ADDIE model was selected because it provides a systematic framework for developing, validating, implementing, and evaluating educational products (Widyastuti, 2019). The implementation of the Equations Dash media trial was carried out using the One Group Pretest-Posttest Design, where the improvement of students’ mathematical problem-solving skills was measured in the same group before and after the intervention.

Participants

This study involved several groups of participants according to the different stages of the research and development process. The participants consisted of expert validators, undergraduate students for the preliminary User Acceptance Test (UAT), and Grade VII junior high school students as the intended users of the developed learning media. The demographic characteristics and roles of each participant group are presented in Table 3.

Table 3. Demographic characteristics, selection criteria, and roles of the participants

Participant Group	Number	Demographic Characteristics	Selection Criteria	Research Role
Subject Matter Expert	1	Mathematics education expert with experience in curriculum and instructional content	Selected based on expertise in mathematics education and curriculum development	Content validation

Media Expert	1	Educational technology expert with experience in instructional media development	Selected based on expertise in educational media design and technology	Media validation
Mathematics Education Undergraduate Students	17	6 males, 11 females; mean age: 20 years	Selected because they possess sufficient pedagogical and technological knowledge to evaluate the usability, navigation, interface design, and functionality of the developed media prior to classroom implementation	Preliminary User Acceptance Test (UAT)
Grade VII Junior High School Students	28	16 males, 12 females; mean age: 13 years	Selected using purposive sampling because they had learned prerequisite algebra concepts but had not previously studied One-Variable Linear Equations using <i>Equations Dash</i>	Field implementation, student response evaluation, and effectiveness testing

The expert validation stage involved one subject matter expert and one media expert to evaluate the content accuracy, instructional quality, interface design, and technical aspects of the developed media. The expert validators were selected using purposive sampling based on predetermined eligibility criteria. Material experts were required to hold at least a master's degree in mathematics education or a closely related field and have at least five years of experience in mathematics teaching, curriculum development, or mathematics education research. Media experts were required to hold at least a master's degree in educational technology, instructional media, computer science education, or a related discipline, with at least five years of professional experience developing, evaluating, or researching educational media.

Before classroom implementation, we conducted a preliminary User Acceptance Test (UAT) with undergraduate students from the Mathematics Education Program. This stage aimed to obtain formative feedback on the usability, navigation, interface consistency, and

overall functionality of the developed media. The undergraduate students were selected because they have sufficient pedagogical and technological knowledge to provide constructive recommendations to improve the product before classroom implementation.

Following revisions based on the expert validation and preliminary UAT results, the revised version of *Equations Dash* was implemented with 28 Grade VII students, who represented the intended users of the developed learning media. During implementation, students completed a learning media response questionnaire to evaluate the media's practicality and usability from the perspective of actual end users. Furthermore, the study examined the effectiveness of the developed media in improving students' mathematical problem-solving skills using a one-group pretest–posttest design.

Research Instruments

To collect data relevant to the study's purpose, the instruments used are classified into two main categories: test instruments and non-

test instruments. The test instruments (Pre-test and Post-test) consist of four descriptive questions designed to measure students' Mathematical Problem-Solving Abilities in PLSV material. These questions are developed by researchers and validated by a math education expert to ensure their validity and relevance. The four question items specifically test the key indicators of Mathematical Problem-Solving Ability proposed by (Pólya, 1945) in PLSV, including: 1) identifying variables and information that are known/questioned, 2) modeling contextual problems into algebraic form, 3) performing equation-solving calculations, 4) evaluating the truth or incorrectness of the solution. All questions aligned with the four indicators of Mathematical Problem-Solving Ability.

Before implementation, the mathematical problem-solving test underwent expert validation and empirical testing. Empirical item validity was examined using item-total correlation analysis, while the internal consistency of the instrument was evaluated using Cronbach's Alpha coefficient.

Before administering the main study, the mathematical problem-solving test was piloted with 20 seventh-grade students from a different class at the same junior high school. These students were not included in the main study but had comparable academic characteristics to the target participants. The pilot data were used to evaluate the instrument's empirical validity using the item-total correlation method. The validity analysis employed Pearson's Product-Moment correlation with a significance level of 0,05. Based on the pilot sample size ($N = 20$), the critical r -value (r -table) was 0,44. Items with correlation coefficients exceeding this value were considered valid and retained for use in the main study.

The results indicated that all four essay items met the validity criterion, and the overall reliability coefficient demonstrated satisfactory internal consistency. A summary of the empirical validity

and reliability testing results is presented in Supplementary Appendix A.

Non-test instruments include various questionnaires that measure the feasibility and practicality of the Equations Dash media. These questionnaires include 1) Subject Matter Expert Test Questionnaire, 2) Media Expert Test Questionnaire, and 3) User Acceptance Test Questionnaire (Student Response Questionnaire). Each questionnaire is carefully designed with indicators aligned with the aspects being evaluated. The subject matter expert test questionnaire evaluates the material's alignment with curriculum standards, content accuracy, and usefulness in achieving learning objectives. The aspects assessed include material aspects (such as suitability for basic competencies, accuracy, and the availability of contextual interactive materials), language aspects (correct, appropriate, and consistent use of language), and presentation aspects (systematic, logical, coherent, and clear presentation of material).

The media expert test assesses the quality of learning media in terms of design, language, and ease of use to ensure the media effectively supports the learning process. In the Scratch-based media design aspect, the indicators assessed include visual quality (such as background design and multimedia animation, text clarity, image presentation, and layout), the use of visuals and audio that support understanding without disrupting focus, and the integration of contextual and interactive animations. The language aspect is assessed based on the quality of language use, while the ease-of-use aspect assesses how user-friendly the Scratch learning media is overall. Material and media experts, including mathematics education experts with special competencies in learning materials and media, validate and assess the designed learning media for relevance and reliability.

The user trial aims to evaluate students' experience with the learning media after

implementation. The User Acceptance Test (UAT) questionnaire was developed based on a set of indicators to ensure the media is not only academically relevant but also easy to use and effective in enhancing the student learning experience. Indicators in UAT include: 1) Display, which evaluates the visual quality of media such as graphic design and color scheme; 2) Content of the Material, which assesses the accuracy and quality of the material presented; 3) Program functionality, which checks the technical aspects, ensuring the program runs smoothly without technical problems such as errors or slow loading; 4) Interest, which measures the extent to which the media is able to attract and retain students' attention; 5) Sound, which evaluates the quality of the audio components; and 6) Usability, which measures the practical benefits of the medium to the user. Each indicator is evaluated through a combination of open-ended and closed-ended questions, ensuring a comprehensive assessment of the learning media's performance and impact. The research instruments are presented in Supplementary Appendix B.

To complement the quantitative findings, semi-structured interviews were conducted with several students after the implementation of Equations Dash. The interviews aimed to explore students' learning experiences, perceptions of the application's interactive features, and the media's perceived contribution to mathematical problem-solving activities. The interview guide included open-ended questions that encouraged participants to describe their experiences using the application.

To obtain qualitative insights from students with different levels of learning achievement, three participants were selected purposively based on their post-test scores. One student represented the highest-achievement group (highest post-test score), one represented the average-achievement group (post-test score closest to the class average), and one represented the lowest-

achievement group (lowest post-test score). This selection aimed to capture diverse learning experiences and perceptions of using Equations Dash across different levels of mathematical problem-solving performance.

The interviews were conducted individually after participants completed the learning activities. Participants were purposively selected to represent different levels of learning achievement and classroom participation. Each interview lasted approximately 10–15 minutes and was recorded. The collected qualitative data were analyzed descriptively by identifying recurring themes related to students' experiences and perceptions of Equations Dash.

To ensure participant confidentiality, each student was assigned an anonymous code consisting of the letter "R" (Respondent) followed by a participant number (e.g., R7, R9, and R17). These codes were used when reporting interview quotations throughout the study.

Research Procedure

This study employed the ADDIE development model as the instructional design framework for developing the interactive learning media. The ADDIE model consists of five systematic phases: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). These phases were carried out sequentially, beginning with identifying instructional needs and concluding with evaluating the final product to ensure its validity, practicality, and effectiveness.

The Analysis phase identified students' learning needs, existing instructional challenges, and curriculum requirements. The Design phase focused on planning the learning objectives, instructional content, user interface, and game mechanics of *Equations Dash*. During the Development phase, the media was created using Scratch and subsequently validated by subject matter and media experts. The Implementation

phase involved classroom trials to evaluate the practicality and effectiveness of the developed media. Finally, the Evaluation phase analyzed the product's overall quality based on expert validation, user responses, and students' learning outcomes.

The learning intervention was implemented in a blended learning environment during one instructional session of 2×40 minutes. The session began with approximately 15 minutes of teacher-led instruction, including apperception, learning motivation, and an introduction to the objectives and procedures of using Equations Dash. This was followed by approximately 45 minutes of independent and collaborative learning activities in which students interacted with the Equations Dash application to solve one-variable linear equation problems. During this phase, the teacher provided guidance only when necessary while students explored the game features and completed the embedded problem-solving tasks. The session concluded with approximately 20 minutes of classroom discussion and reflection, during which students shared their experiences, discussed solution strategies, and received feedback from the teacher. This allocation of learning activities reflects the integration of direct instruction and technology-supported independent learning, which characterizes the blended learning approach implemented in this study (Graham, 2006).

Data Analysis

Data analysis in this study is divided into two main focuses: validity/practicality analysis and effectiveness analysis. Data from the expert questionnaire and the student response questionnaire were analyzed using percentages, then converted into qualitative categories (Very feasible, feasible, unfeasible, very unfeasible) to describe the media's feasibility and practicality. The validity of the learning media and the

practicality of its implementation were determined using percentage analysis.

To facilitate the interpretation of percentage scores obtained from expert validation and user response questionnaires, percentage values were classified into five qualitative categories using an equal-interval categorization approach (Cohen et al., 2018). This approach is widely employed in educational instrument evaluation to convert quantitative scores into meaningful qualitative interpretations (Widoyoko, 2018). Interpretation criteria for percentage scores are presented in Supplementary Appendix C.

To facilitate interpretation of the User Acceptance Test (UAT) results, we classified the obtained percentage scores into five categories using equal-interval classification. This categorization was applied consistently to interpret the practicality level of each evaluated aspect. Percentage values were classified into five qualitative categories using an equal-interval categorization approach (Cohen et al., 2018). Score categorization for the user acceptance test is presented in Supplementary Appendix C.

The effectiveness of the media, Pre-test and Post-test score data, was analyzed through a series of statistical tests. The first step is to conduct the prerequisite analyses, namely the Normality Test and the Homogeneity Test, to determine the appropriate inferential statistical test. Increase in Mathematical Problem-Solving Ability is measured using the Normalized Gain (N-Gain) calculation. This N-Gain formula serves to eliminate the influence of the initial score, and the results of the improvement are grouped into criteria: High, Medium, or Low, which is the basis for concluding the level of effectiveness of the Equations Dash media in improving students' Mathematical Problem-Solving Abilities. The Equations Dash media is declared effective if the N-Gain score is in the medium or high category. The interview data were analyzed descriptively

by identifying recurring opinions and experiences expressed by the participants.

■ RESULT AND DISCUSSION

Characteristics and Validity of the Developed Media

This section presents the characteristics of the developed Equations Dash learning media, along with the results of expert validation. The discussion covers the needs analysis underlying the development process, the media's main features, and the evaluation of its content and technical quality by subject-matter and media experts.

In the analysis stage, an assessment of needs is carried out to identify the challenges and requirements faced by students in understanding the material on one-variable linear equations. This analysis involved observation and interviews with mathematics teachers at one of the MTS in Karawang district. The chosen learning topic, "One-Variable Linear Equations," as it is an important component of learning Algebraic Structures. By the end of Phase D, students are expected to achieve certain learning outcomes, including identifying variables and known/unknown information, performing equation-solving calculations, and solving contextual problems related to one-variable linear equations.

A needs analysis was conducted through classroom observations and interviews with mathematics teachers at the selected junior high school. The findings indicated several instructional challenges in teaching one-variable linear equations. The learning process remained dominated by teacher-centered instruction using conventional board explanations, resulting in limited student engagement and fewer opportunities for active mathematical exploration. Teachers also reported difficulty using interactive learning media that could effectively visualize abstract algebraic concepts and guide students through systematic problem-solving processes.

Consequently, students tended to struggle with contextual problems, plan solution strategies, and evaluate the correctness of their answers. These findings confirmed the need to develop an interactive learning medium that supports students' mathematical problem-solving skills in a more engaging and structured way.

The needs analysis identified several major instructional gaps: (1) mathematics learning was still dominated by lecture-based instruction; (2) teachers had limited experience in using interactive digital learning media; (3) existing learning resources mainly emphasized procedural calculations rather than mathematical problem-solving processes; and (4) students showed low engagement and motivation during learning activities involving one-variable linear equations. These findings became the primary basis for designing the Equations Dash learning media.

The Equations Dash game integrates one-variable linear equation material through an engaging, contextual approach. The development of the game focuses on several key indicators of mathematical problem solving proposed by (Pólya, 1945) : (1) understanding the basic concepts of a one-variable linear equation, (2) identifying the main components, (3) solving a one-variable linear equation, and (4) evaluating the correctness of a solution. The game is structured in stages to strengthen mathematical problem-solving skills. For example, the activity determines the coefficients and variables of an equation, solves a one-variable linear equation from a contextual problem, and checks the correctness of the solution. This gamification approach is expected to improve students' mathematical problem-solving skills.

The multimedia design is created by defining the main concept, based on the game Geometry Dash and focused on one-variable linear equations. Therefore, the multimedia is named "Equations Dash". A team of three develops a storyboard that depicts each scene and gameplay.

These materials align with basic competencies on one-variable linear equations. Equations Dash starts with an attractive visual frame and a 1024x768 background resolution. The title “Equations Dash” is displayed with dynamic animation effects, immediately grabbing the player’s attention. At the initial view, you can see the main menu that displays several sections, including the profile menu (containing the identity of the multimedia developer), the indicator menu (outlining the expected learning objectives), the material menu (which includes interactive materials and questions), the how-to-play menu (showing how to play), and the gameplay menu (displaying 5 game levels, which contain questions on each level, difficulty level, and cognitive level). The material for the topic of one-variable linear equations comes from textbooks and additional online references, while the visual design is created in Canva.

Audio elements come from Geometry Dash background music, from the main menu to

gameplay. Each level has different audio depending on the difficulty, creating a different impression as players move through each challenge. This audio plays a crucial role in enhancing the gaming experience. When players enter the material menu, they hear audio instructions that match the material presented, such as specific instructions for the activities required at each stage. Adding audio further supports the game’s educational aspect, keeping students engaged while reinforcing understanding of one-variable linear equations.

The development of game-based learning media is carried out using the Scratch application, in accordance with the plan from the previous stage. Here are some game looks designed with Scratch for the topic of single-variable linear equations. An overview of the Main Interfaces of the Equations Dash is shown in Figure 1.

The game is easily accessible at <https://bit.ly/EquationDash> and provides a user-friendly introduction for new players. Figure 1 presents



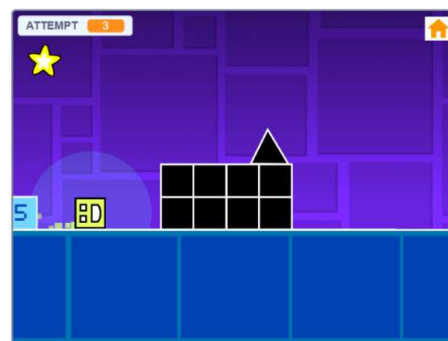
(a) Main Menu



(b) Learning Material



(c) Game Level



(d) Game Play

Figure 1. Overview of the main interfaces of equations dash

the main interfaces of the Equations Dash interactive learning media. The application includes several integrated menus: the main menu, learning material, game levels, gameplay interface, and level completion screen. These features support students throughout the learning process, starting with conceptual understanding and progressing through increasingly challenging problem-solving activities. The gameplay requires students to select the correct mathematical solution while responding to interactive challenges. Incorrect responses require students to repeat the activity, thereby encouraging reflection and reinforcing conceptual understanding.

The learning material menu provides interactive explanations, contextual examples, and various practice activities such as drag-and-drop tasks, multiple-choice questions, and short-answer exercises. Meanwhile, the gameplay interface integrates mathematical questions into a game environment where students must identify the correct solution while avoiding obstacles. At the end of each level, the system provides immediate feedback, encouraging students to review their answers before moving on to more complex challenges.

If students select an incorrect answer, they are required to repeat the level. This mechanism encourages learners to re-evaluate their previous reasoning, identify misconceptions, and revise their solution strategy before attempting the problem again. Consequently, the gameplay explicitly supports the “looking back” stage in Polya’s mathematical problem-solving process.

Unlike conventional educational games that primarily emphasize entertainment, Equations Dash intentionally integrates each gameplay element with specific cognitive processes involved in mathematical problem solving. For example, the obstacle mechanism requires students to reconsider their previous responses whenever an incorrect answer is selected, thereby encouraging self-evaluation and reflective

thinking. Similarly, the progressive level structure supports strategic planning by gradually increasing problem complexity, while immediate feedback helps students identify misconceptions and refine their reasoning before moving on to subsequent tasks. Consequently, the game mechanics function not merely as motivational elements but also as instructional scaffolds that facilitate each stage of Polya’s problem-solving process.

As summarized in Table 2, every interactive feature of Equations Dash was intentionally designed to support a particular stage of mathematical problem solving rather than merely increasing students’ engagement.

After the development of the “Equations Dash”, repeated testing was carried out by the creators and developers with several revisions before the implementation tests. To ensure the multimedia’s accuracy and feasibility, the researchers conducted validity testing by validating the material and media. Two lecturers in Mathematics Education at a university in Bandung, West Java, participated in validating the content and media design. Based on their feedback, the multimedia tool was considered feasible, with minor revisions before implementation tests. The functionality test was then conducted with undergraduate mathematics education students at a university in Bandung, West Java. Validation of the feasibility of the multimedia game was carried out by two experts: a material expert and a learning media expert. Subject matter experts gave a validity score of 85%, while learning media experts gave 89%. Both scores are in the “valid” category. These results confirm that the multimedia meets the criteria for use in the educational environment, in both material content and media quality. Equations Dash has obtained a copyright certificate for the game from the Ministry of Law and Human Rights, number EC002025202209.

Although the validation results indicated that the Equations Dash learning media achieved a

very valid category based on assessments by both the material expert and the media expert, several constructive suggestions were provided to further improve the product's quality before classroom implementation. The material expert emphasized improving the clarity of several mathematical problems, ensuring consistency between the learning objectives and the game content, and refining the wording of several instructional texts to avoid ambiguity. Meanwhile, the media expert recommended improving the interface's visual consistency, enhancing text readability through appropriate font size and layout adjustments, and simplifying the navigation system to create a more user-friendly learning experience. These suggestions were considered valuable in strengthening both the pedagogical quality and usability of the developed learning media. Revisions made based on expert validation are presented in Supplementary Appendix D.

We carefully considered and incorporated all validator recommendations into the revised version of Equations Dash. The revision process focused on improving both the instructional quality and technical usability of the learning media without changing its core learning objectives. After implementing all suggested improvements, the media was considered more appropriate in terms of content accuracy, interface design, instructional clarity, and user interaction. Therefore, the revised version of Equations Dash was deemed suitable to proceed to the practicality testing stage involving students and mathematics teachers in the classroom.

Practicality and Student Responses

After the developed media had been declared valid by the experts, a practicality evaluation was conducted. Experts declared the developed media valid, the researchers conducted a practicality evaluation through a User Acceptance Test (UAT). This stage aimed to investigate users' perceptions regarding the

usability, interface quality, functionality, and overall learning experience provided by Equations Dash.

Before implementing the User Acceptance Test (UAT), the school administration granted permission to conduct the study. The mathematics teacher and participating students were informed about the study's objectives and procedures, and participation was voluntary. The collected data were used solely for research purposes, and participants' identities were kept confidential throughout the study. Therefore, the data collection procedures complied with the ethical principles for educational research involving human participants.

This Equations Dash was tested to collect user feedback. The development of the Scratch-based learning media was completed successfully, and preliminary functionality and usability testing was then conducted. Functionality testing aims to ensure that all application features operate according to predefined specifications. This test used User Acceptance Testing (UAT) to evaluate user responses to the learning media. A total of 17 Mathematics Education students at a university in West Java participated by completing questionnaires distributed through Google Forms.

The selection of undergraduate students in Mathematics Education as participants in the User Acceptance Test (UAT) was based on the consideration that they possess fundamental knowledge of mathematics learning media and are capable of providing more objective evaluations regarding usability, interface design, readability, program functionality, and overall media performance. In this study, the UAT was intended to evaluate the media's practicality and functionality before implementation with junior high school students as the primary target users. Furthermore, mathematics education students, as prospective teachers, were expected to provide pedagogical feedback on the media's suitability for mathematics learning activities. Meanwhile, the effectiveness testing of the media in improving

mathematical problem-solving skills was conducted with seventh-grade junior high school students as the main research subjects.

The questionnaire included 12 closed-ended statements and 1 open-ended statement to support the analysis of responses. Closed statements include: In-game material is easy to understand (Q1); Complete materials and according to basic competencies (Q2); Image display & easy-to-read text (Q3); Easy-to-understand menu & button layout (Q4); Features & buttons working well (Q5); Attractive colors, animations, and designs (Q6); Explanatory audio

& clear backsound (Q7); The game is easy to operate without explanation (Q8); Users are happy to use the game (Q9); Interested in using games in learning (Q10); Enthusiastic about continuing to use the game (Q11); Games are beneficial in learning (Q12). The open question is: What are your criticisms and suggestions about this game? (Q13). Prospective mathematics teachers showed a very positive attitude towards the Equations Dash game, with an average score of 87.75% in all indicators. The distribution of User Responses by Category is shown in Figure 2.

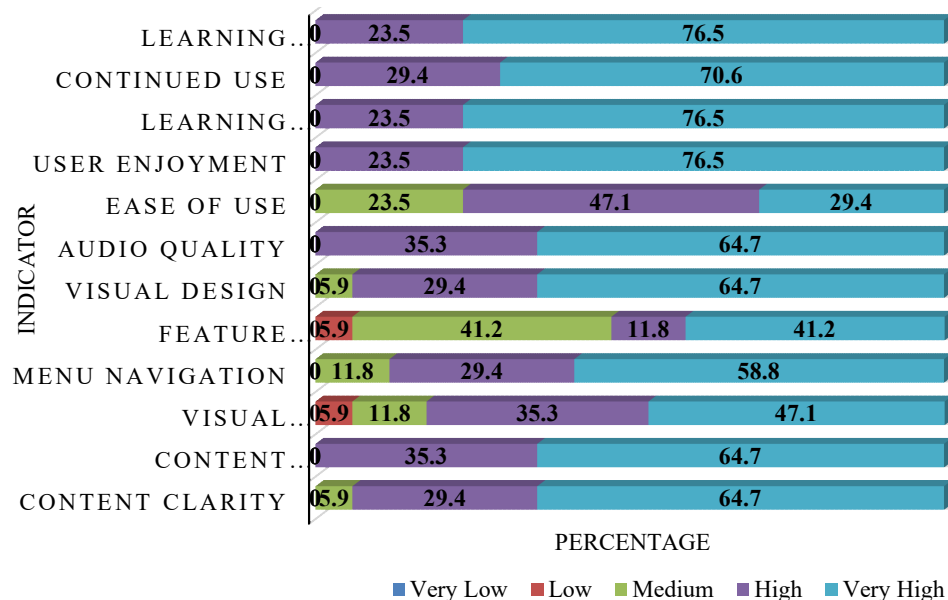


Figure 2. Distribution of user responses by category

Figure 2 illustrates the distribution of participants' responses across five practicality categories for each User Acceptance Test (UAT) indicator. Most responses were concentrated in the Very High and High categories, indicating that participants accepted Equations Dash positively. Several indicators, particularly Items 9–12, showed that more than 70% of respondents rated the media as Very High. Meanwhile, Item 5 showed the greatest variation in responses, although most participants still rated it in the Medium to Very High categories. Overall, the

distribution demonstrates that the developed learning media achieved a consistently high level of practicality across all evaluated aspects.

These findings align with previous studies showing that educational games generally receive positive feedback. Participants' responses regarding various aspects of the game revealed both positive feedback and areas for improvement. In response to question 13, related to display, R17 respondents found the display attractive, using colors and visuals that could attract students' interest. R7 agreed that the

image display is good and that the features and buttons are user-friendly, although they noted that the text is too small and the resolution sometimes looks broken.

Regarding the material, respondent R9 said the material was very easy to understand, and the learning stages were well arranged; R3 agreed and commented that more complete instructions could be added at the beginning to avoid confusion when doing activities in the material. Regarding gameplay and functionality, R6 mentioned that the game is really fun; after learning the material, we are presented with an exciting game. R11 thinks it is very fun to use a method like this; if it can be developed again, it could be a great option for children who like to play games. Linked to the response, R10 commented that I really liked the game design that lifted the theme from Geometry Dash, so it was reminiscent of childhood memories, and the overall appearance was interesting. They really like and are enthusiastic about playing the game, even though bugs still occur; R13 says they can still work if reloaded, such as a button that does nothing when clicked. Regarding the motivational impact of games, R5 states that these games are interesting and can motivate students to learn math, offering an interesting alternative to reading books. R2 agrees, noting that games motivate students by combining learning with fun challenges, thus enhancing the learning experience through gamification.

Based on Table 10 and the interview results, the learning media “Equations Dash” received very positive feedback, with an average user rating of 87.75% across all evaluated aspects. This shows that users rate the media in the “very decent” category.

Effectiveness on Learning Outcomes

Following the practicality evaluation, the study examined the effectiveness of Equations Dash through classroom implementation with Grade VII students. The effectiveness analysis focused on improvements in students’

mathematical problem-solving skills, measured using pretest and posttest scores.

The implementation stage is a media trial on the research sample. Before the learning process begins, a pre-test measures students’ initial mathematical problem-solving ability. The learning was implemented using Equations Dash media. During implementation, the teacher acted solely as a facilitator by providing instructions, managing classroom activities, and assisting students with technical issues related to using Equations Dash. The teacher did not provide direct explanations or solutions to the mathematical problems contained in the application. The classroom learning process uses a blended learning model that combines face-to-face activities with interactive activities based on the Equations Dash media developed.

Before using Equations Dash, the teacher briefly introduced the learning objectives and provided instructions for using the application. During implementation, students actively used Equations Dash features to solve mathematical problems individually and collaboratively. Most participants navigated the application independently after a brief introduction from the teacher. The interactive gameplay encouraged students to explore different solution strategies, evaluate their answers through immediate feedback, and repeat the activities whenever incorrect solutions were obtained. These learning experiences promoted active participation and sustained engagement throughout the learning session.

Participants also showed enthusiasm as they completed progressively challenging levels in the application. Rather than passively receiving explanations from the teacher, students directly identified mathematical information, planned solution strategies, carried out calculations, and evaluated the correctness of their responses through the interactive features embedded in the learning media.

Throughout the activities, students progressed through the stages of mathematical

problem solving proposed by Pólya (1945). They first identified the information presented in each contextual problem, planned appropriate solution strategies, implemented the required mathematical procedures, and finally evaluated their answers using the immediate feedback provided by the application.

To illustrate students' problem-solving performance, Table 4 presents the reconstructed

solution of one participant whose achievement was classified as the standard category based on the posttest results. This participant was selected because the solution reflects the typical problem-solving process most students demonstrated after using the Equations Dash learning media. Therefore, the reconstruction illustrates students' reasoning rather than representing the highest or lowest level of achievement.

Table 4. Reconstruction of a student's mathematical problem-solving process based on polya's stages

Polya's Stage	Before Using Equations Dash (Pretest)	After Using Equations Dash (Posttest)
Understanding the Problem	The student identified only part of the known information and omitted important details.	The student correctly identified all known and required information from the problem.
Devising a Plan	The student selected an inappropriate solution strategy and did not relate the problem to the relevant mathematical concept.	The student selected an appropriate strategy and correctly formulated the required linear equation.
Carrying Out the Plan	Computational procedures contained several errors, leading to an incorrect solution.	The student performed the calculations systematically and obtained the correct solution.
Looking Back	The student did not verify the obtained answer.	The student rechecked the solution and confirmed its correctness according to the problem context.

Table 4 illustrates the reconstruction of a representative student's mathematical problem-solving process before and after using Equations Dash based on Polya's problem-solving framework. Before the intervention, the student struggled to identify relevant information, select appropriate solution strategies, and verify the answers. After using Equations Dash, the student showed noticeable improvement across all four stages of problem-solving. The interactive learning activities, immediate feedback, and progressively structured challenges embedded within the application appeared to support students in developing more systematic and reflective problem-solving processes.

The evaluation stage involves a comprehensive assessment of the effectiveness and quality of the developed learning media. This

process aims to measure how well the multimedia learning tools achieve the desired learning objectives. Mathematics education students, who acted as UAT respondents, evaluated the multimedia "Equations Dash" using a questionnaire. A total of 17 students participated in the survey, which included 13 questions regarding aspects such as appearance, materials, functionality, engagement, sound, and usability. The questionnaire results showed that 87.75% of students liked the learning media "Equations Dash".

The results of the media effectiveness test were carried out by comparing students' mathematical problem-solving skills before and after using "Equations Dash" multimedia. Initially, a pre-test measured students' understanding before using the media. Afterward, students

interacted with the multimedia during their learning process, and a post-test assessed their understanding after using the medium.

Before conducting the hypothesis test, a normality test was performed using the Shapiro–Wilk test because the sample size was less than 50. The results showed that the pre-test data had a significance value of 0.120 (> 0.05), indicating that the data were normally distributed. Meanwhile, the post-test data had a significance value of < 0.001 (< 0.05), indicating that the data were not normally distributed. Because one dataset did not meet the assumption of normality, the analysis continued using the non-parametric Wilcoxon Signed-Rank Test.

The results of the Wilcoxon Signed-Rank Test showed a Z value of -4.624 with an Asymp. Sig. (2-tailed) value of < 0.001 . The significance

value, which was lower than 0.05, indicates a statistically significant difference between students' pre-test and post-test scores after using the Equations Dash learning media. Therefore, the Equations Dash learning media effectively improved students' mathematical problem-solving skills.

Based on students' learning outcomes, the average pre-test score before using the Equations Dash media was 33.75. In contrast, the average post-test score increased to 96.75 after implementing the media. Furthermore, the N-Gain analysis yielded a score of 0.95, which was categorized as high. These findings support the Wilcoxon Signed-Rank Test results, indicating that the Equations Dash media effectively improves students' mathematical problem-solving skills. The results of normality and Wilcoxon tests are summarized in Table 5.

Table 5. Results of normality and wilcoxon tests

Variable	N	Min	Max	Mean	SD	Shapiro-Wilk
Pre-test	28	10	60	33.75	13.96	0.120
Post-test	28	86	100	96.75	3.70	< 0.001
N-Gain				0.95		
Wilcoxon Signed-Rank Test				Z = -4.624		P < 0.001

In terms of learning outcomes, the average pre-test score before using the Equations Dash multimedia game is 33.75. After using the multimedia game, the average post-test score increased significantly to 96.75. Analysis using

the N-Gain formula yielded an N-Gain score of 0.95, further demonstrating significant improvement in students' conceptual understanding after using the multimedia game. The increase in the score is shown in Figure 3.

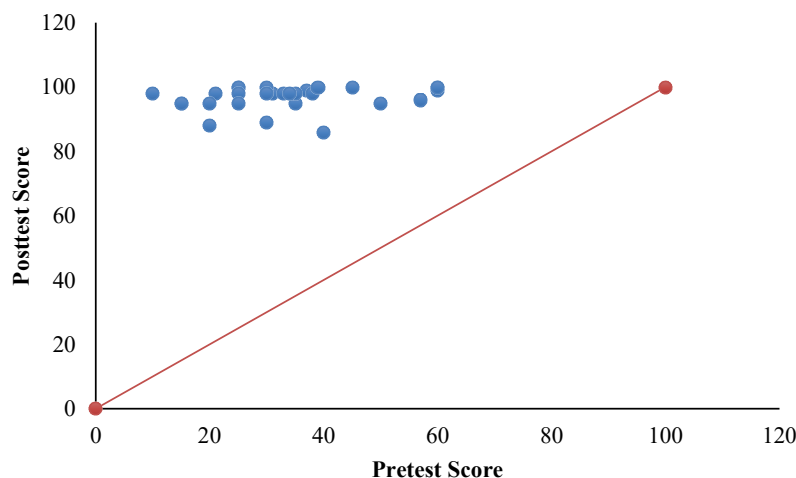


Figure 3. Scatter plot of pretest and posttest scores

Figure 3 shows the relationship between students' pretest and posttest scores in a scatterplot with a reference diagonal line ($y=x$). Each point represents one participant. All data points lie above the diagonal line, indicating that every participant obtained a higher posttest score than a pretest score. Furthermore, the relatively large vertical distance between most points and the reference line demonstrates substantial learning gains across participants after using Equations Dash.

The absence of data points below the reference line indicates that none of the participants experienced a decline in learning outcomes. This finding further supports the quantitative N-Gain analysis, suggesting that the developed learning media consistently improved students' mathematical problem-solving performance within the implemented instructional context.

Although quantitative N-Gain values for each problem-solving indicator were unavailable, qualitative analysis of students' solution processes indicates improvements across all four stages of Polya's framework. Students better identified known information, planned more systematically, used more accurate mathematical procedures, and showed greater awareness of verifying their final answers after using Equations Dash. Each student showed significant progress in their conceptual comprehension, as confirmed by an N-Gain score of 0.95, which categorized the improvement as "very high". Interview transcripts provide a more comprehensive understanding.

The substantial improvement in students' mathematical problem-solving scores should be interpreted in relation to the instructional characteristics of Equations Dash and the participants' initial level of understanding. The relatively low pretest mean score 33,75 indicates that many students had limited prior mastery of one-variable linear equations before the intervention. Consequently, there was

considerable room for improvement during the learning process. Through Equations Dash, students received interactive learning activities, immediate corrective feedback, contextual problem-solving tasks, and opportunities for repeated practice, all of which have been recognized as important factors in facilitating conceptual understanding and mathematical problem-solving skills.

Previous studies on game-based and interactive mathematics learning media have reported similar findings. Several studies have shown that digital learning environments integrating immediate feedback, contextual learning tasks, and active student engagement can produce substantial improvements in mathematical understanding and problem-solving performance, particularly when students initially demonstrate low achievement levels (Possumah & Qohar, 2024a; S. Sari et al., 2024). Therefore, although the obtained N-Gain value 0,95 appears relatively high, it remains theoretically plausible within the context of intensive interactive learning supported by structured instructional media.

Nevertheless, the high learning gains observed in this study should be interpreted within the specific context of the participants, instructional duration, and learning environment. Future studies with larger, more diverse samples are recommended to examine the generalizability of these findings.

The improvement in students' mathematical problem-solving skills, as reflected by the N-Gain results, should be interpreted within the context of the instructional design implemented in this study. Although the blended learning approach incorporated teacher facilitation and collaborative activities, the teacher's role was intentionally limited to providing procedural guidance, facilitating classroom activities, and ensuring students could operate the learning media effectively. The teacher did not provide direct solutions to the mathematical problems presented

in Equations Dash. Therefore, students' engagement with the interactive tasks, immediate feedback, and progressively structured problem-solving activities within the media constituted the primary learning experience during the intervention.

Accordingly, the effectiveness observed in this study should be understood as the result of implementing Equations Dash within a blended learning environment rather than as the isolated effect of the media alone. This instructional context reflects authentic classroom practice, where digital learning media are generally integrated with teacher facilitation instead of replacing the teacher's role. Consequently, the findings demonstrate the practical effectiveness of Equations Dash as a learning medium when used to support mathematics instruction in real classroom settings.

To enrich the quantitative findings, several interview excerpts are presented below to illustrate students' experiences while using Equations Dash. During the follow-up interview, students reflected, "After playing the Equations Dash game and listening to the teacher's explanation, I better understand how to determine the components of a variable equation, determine the general formula of a single-variable linear equation, and solve a single-variable linear equation." (R9). It shows how interactive multimedia integration can significantly improve mathematical problem-solving capabilities by clarifying the stages of continuous learning. The observed increase is in line with existing research, which shows that interactive media improves learning outcomes (M. R. Sari & Qohar, 2023), Increase student involvement in solving mathematical problems (Amir et al., 2018b; Barana et al., 2020) and increases students' motivation to learn (Solikhatun & Sari, 2023).

The findings of this study are consistent with those reported by Barana et al., who also found

that interactive digital learning media can enhance students' mathematical learning outcomes. The similarity between the two studies lies not only in the positive learning outcomes but also in the instructional mechanisms embedded within the learning media. Both Equations Dash and the digital learning environment developed by Barana et al. incorporate interactive problem-solving activities, immediate feedback, and active student engagement, enabling learners to construct mathematical understanding through continuous practice rather than passive information reception.

Nevertheless, the present study differs from Barana et al. in several respects. While Barana et al. primarily emphasized digital learning activities, Equations Dash integrates game-based challenges, progressively structured levels, and contextual mathematical problems within a blended learning environment. These additional instructional features may have contributed to the high level of student engagement and the substantial improvement in mathematical problem-solving skills observed in the present study.

Overall, the findings show that the "Equations Dash" multimedia offers an attractive design, with visually appealing characters, colors, and animations. The material on one-variable linear equations is easy to understand, and the medium is highly interactive, making it an effective tool for students. In addition to questionnaires, we also conducted interviews to gain deeper insights into users' experiences with this multimedia. Participants shared various views on the game's advantages and areas for improvement. While respondents praised the nostalgic, catchy visuals, they also noted some issues. For example, some mentioned that the text size is too small and the image resolution appears distorted, which can affect user convenience. Clear, easy-to-read visuals are essential to increase student engagement and understanding in digital learning. (Yousuf & Conlan, 2020).

Regarding the content, all respondents agreed that the material was complete and aligned with learning objectives and educational standards, with no conceptual errors. This aligns with previous research highlighting the importance of accurate content for effectiveness. (Gürefe, 2018) However, some technical issues were noted, such as the sprite not disappearing when switching screens or no reaction when clicking the button, indicating the need for technical improvements.

The Equations Dash learning media was developed using Scratch 3.0 Online. During development, a minor technical issue occurred in which some sprites occasionally remained visible during screen transitions. This issue was addressed by refining the sprite visibility control and scene-switching scripts within the Scratch environment. The issue was technical in nature and did not affect the functionality or educational objectives of the learning media.

The game is highly appreciated for improving students' mathematical problem-solving abilities by combining learning with play. This approach makes the learning process more engaging and challenging, in line with previous studies that emphasized the role of educational games in improving mathematical problem-solving skills (Al-Hassan et al., 2025b).

The results show that users responded positively to the educational games developed, highlighting their potential for effective use with Scratch software. Previous research supports these findings, showing that learning media created with Scratch often gets positive feedback from students (Belessova et al., 2024; Wen et al., 2023). In addition, the ADDIE model is effective in producing quality, practical, and functional learning media, as shown in various studies (Nandyansah et al., 2020; Possumah & Qohar, 2024b). Integrating interactive game elements further encourages student participation and increases motivation, which in turn supports

mathematical problem-solving skills. Students' high interest in this game is likely to lead to better learning outcomes and a stronger understanding of the material. Therefore, game-based learning media have significant potential to address various challenges in mathematics education and improve students' academic performance.

One limitation of this study is that the effectiveness of Equations Dash was evaluated within a blended learning environment involving teacher facilitation. Therefore, the independent effect of the learning media could not be completely separated from the influence of instructional support. Future studies are encouraged to compare Equations Dash with other instructional approaches or employ controlled experimental designs to isolate the contribution of the developed media.

■ CONCLUSION

Based on the results, the development of mathematics learning media for one-variable linear equation material using the Scratch application was completed according to the ADDIE stages, although some aspects still need improvement. ADDIE's process of analysis, design, development, implementation, and evaluation was implemented effectively. User responses to these media outlets were overwhelmingly positive, with an "excellent" rating and an average score of 87.75% across all evaluated aspects. In addition, the findings indicate that Equations Dash can improve students' mathematical problem-solving skills when implemented in a blended learning environment. For future development, further research on Scratch-based learning media across different topics is recommended to expand the scope and impact of these educational tools.

Despite the encouraging findings, this study has several limitations. The study evaluated the effectiveness of Equations Dash using a One-Group Pretest-Posttest Design without a control group. Consequently, the observed improvements

in students' mathematical problem-solving skills cannot be attributed exclusively to the learning media, as other instructional factors may also have contributed to the learning outcomes. Future research should therefore employ controlled experimental designs with comparison groups and larger samples to strengthen the causal interpretation and generalizability of the findings.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing and revision of this manuscript, the authors used OpenAI to assist with language refinement, grammar improvement, and restructuring several sections in response to reviewers' comments. All generated suggestions were carefully reviewed, verified, and edited by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the final published manuscript.

■ REFERENCES

- Aguiar, K., da Ponte, J. P., & Mata-Pereira, J. (2024). The use of algebraic language in grade 9: Strategies, meanings, and difficulties. *PNA*, 18(4), 391–414. <https://doi.org/10.30827/pna.v18i4.27382>
- Al-Hassan, O. M., Alhasan, L. M., AlAli, R. M., Al-Barakat, A. A., Al-Saud, K. M., & Ibrahim, N. A. (2025a). Enhancing early childhood mathematics skills learning through digital game-based learning. *International Journal of Learning, Teaching and Educational Research*, 24(2), 186–205. <https://doi.org/10.26803/ijlter.24.2.10>
- Al-Hassan, O. M., Alhasan, L. M., AlAli, R. M., Al-Barakat, A. A., Al-Saud, K. M., & Ibrahim, N. A. (2025b). Enhancing early childhood mathematics skills learning through digital game-based learning. *International Journal of Learning, Teaching and Educational Research*, 24(2), 186–205. <https://doi.org/10.26803/ijlter.24.2.10>
- Amir, M. F., Hasanah, F. N., & Musthofa, H. (2018a). Interactive multimedia based mathematics problem solving to develop students' reasoning. *International Journal of Engineering and Technology(UAE)*, 7(2.14 Special Issue 14), 272–276.
- Amir, M. F., Hasanah, F. N., & Musthofa, H. (2018b). Interactive multimedia based mathematics problem solving to develop students' reasoning. *International Journal of Engineering and Technology(UAE)*, 7(2.14 Special Issue 14), 272–276. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85067270758&partnerID=40&md5=94464a0e9f8f0af3eb947578b0890ed5>
- Anagnostopoulou, E. (2024). Digital role-playing games as a novel approach to learning mathematics: A quantitative analysis. *Adults Learning Mathematics International Journal*, 18(1), 49–69.
- Barana, A., Boffo, S., Gagliardi, F., Garuti, R., & Marchisio, M. (2020). Empowering engagement in a technology-enhanced learning environment. In M. Rehm, J. Saldien, & S. Manca (Eds.), *Smart Innovation, Systems and Technologies* (Vol. 158, pp. 75–77). Springer. https://doi.org/10.1007/978-981-13-9652-6_7
- Belessova, D., Ibashova, A., Zhidebayeva, A., Shaimerdenova, G., & Nakhipova, V. (2024). The impact of “scratch” on student engagement and academic performance in primary schools. *Open Education Studies*, 6(1). <https://doi.org/10.1515/edu-2022-0228>
- Branch, R. M. (2009). *Instructional Design: The ADDIE Approach* (1st ed.). Springer Science+Business Media, LLC.
- Çakýrođlu, Ü., & Muđtuođlu, E. (2025). Mathematical thinking behind coding:

- Promoting generalization skills via Scratch. *International Journal of Science and Mathematics Education*, 23(7), 2375–2396. <https://doi.org/10.1007/s10763-025-10556-9>
- Calder, N. (2018). Using scratch to facilitate mathematical thinking. *Waikato Journal of Education*, 23(2), 43–58. <https://doi.org/10.15663/wje.v23i2.654>
- Cameron, R. A. (2025). ‘The green tick’: how instant feedback shaped self-efficacy in a first-year mathematics course. *International Journal of Mathematical Education in Science and Technology*, 56(12), 2496–2512. <https://doi.org/10.1080/0020739X.2025.2574947>
- Chang, Y.-S. (2021). Applying the ARCS motivation theory for the assessment of AR digital media design learning effectiveness. *Sustainability (Switzerland)*, 13(21). <https://doi.org/10.3390/su132112296>
- Chen, Y., Zhao, Y., & Wang, M. (2024). An empirical study on the effect of gamified teaching in Scratch courses on developing elementary students’ computational thinking. *2024 13th International Conference on Educational and Information Technology, ICEIT 2024*, 78–83. <https://doi.org/10.1109/ICEIT61397.2024.10541025>
- Chiang, F.-K., & Qin, L. (2018). A Pilot study to assess the impacts of game-based construction learning, using Scratch, on students’ multi-step equation-solving performance. *Interactive Learning Environments*, 26(6), 803–814. <https://doi.org/10.1080/10494820.2017.1412990>
- Chikurteva, A., Chikurtev, D., Bogdanova, N., & Blagoeva, E. (2025). Application of ICT in interactive learning environments for emergency response training. In N. Dobrinkova & S. Fidanova (Eds.), *Lecture Notes in Networks and Systems*: 883 LNNS (pp. 194–203). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-74707-6_21
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge.
- Dayron, R., Angel, E., Milton, M., Gabriela, T., & Michael, V. (2025). Visual programming with Scratch to strengthen computational thinking in engineering education. In P. M.M.L., T. J., & M. R.A.R. (Eds.), *Proceedings of the LACCEI International Multi-conference for Engineering, Education and Technology* (Number 2025). Latin American and Caribbean Consortium of Engineering Institutions. <https://doi.org/10.18687/LACCEI2025.1.1.1072>
- Diab, H., Daher, W., Rayan, B., Issa, N., & Rayan, A. (2024). Transforming science education in elementary schools: the power of PhET simulations in enhancing student learning. *Multimodal Technologies and Interaction*, 8(11). <https://doi.org/10.3390/mti8110105>
- Fahrudin, D., & Pramudya, I. (2019). The analysis of mathematic problem solving ability by Polya’s steps on material trigonometric reviewed from self-regulated learning. *Journal of Physics: Conference Series*, 1254(1). <https://doi.org/10.1088/1742-6596/1254/1/012076>
- Fitria, W., Susilana, R., & Priatna, N. (2025). Investigation of the impact online single and multiple representation scaffolding on mathematical concept mastery and mathematical problem-solving skill. *Journal on Mathematics Education*, 16(2), 709–728. <https://doi.org/10.22342/jme.v16i2.pp709-728>
- Fitriani, F., Hayati, R., Sugeng, S., Srimuliati, S., & Herman, T. (2022). Students’ ability to solve mathematical problems through

- Polya steps. *Journal of Engineering Science and Technology*, 17, 25–32.
- Gökçe, S., & Yenmez, A. A. (2023). Ingenuity of scratch programming on reflective thinking towards problem solving and computational thinking. *Education and Information Technologies*, 28(5), 5493–5517. <https://doi.org/10.1007/s10639-022-11385-x>
- Graham, C. R. (2006). Blended learning systems: definition, current trends, and future directions. In C. J. Bonk & C. R. Graham (Eds.), *Handbook of Blended Learning: Global Perspectives, Local Designs* (1st ed., pp. 3–21). Pfeiffer.
- Gürefe, N. (2018). Mathematical language skills of mathematics prospective teachers. *Universal Journal of Educational Research*, 6(4), 661–671. <https://doi.org/10.13189/ujer.2018.060410>
- Herdianto, E. N., & Indriati, D. (2020). ICT-based learning media to enhance students' problem-solving ability in efforts to face the industrial revolution 4.0. In S. S., S. null, S. null, N. D.A., & P. R. (Eds.), *Journal of Physics: Conference Series* (Vol. 1511, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1511/1/012097>
- Hidayat, W., Rohaeti, E. E., Hamidah, I., & Putri, R. I. I. (2023). How can Android-based trigonometry learning improve the math learning process? *Frontiers in Education*, 7. <https://doi.org/10.3389/feduc.2022.1101161>
- Ke, F., Dai, C.-P., & West, L. (2024). Mathematical experience in game-based problem-solving. *Journal of Computer Assisted Learning*, 40(3), 1083–1097. <https://doi.org/10.1111/jcal.12938>
- Lähteenmäki, H., Hurme, J., & Porras, P. (2024). Design of interactive STACK exercises using JSXGraph for online course: exploring strategies for supporting students with mathematical challenges. In O. Poquet, A. Ortega-Arranz, O. Viberg, C. I.-A., B. McLaren, & J. Jovanovic (Eds.), *International Conference on Computer Supported Education, CSEDU - Proceedings* (Vol. 2, pp. 549–556). Science and Technology Publications, Lda. <https://doi.org/10.5220/0012684600003693>
- Leow, W. M. F., & Huang, W. (2021). Exploring the effectiveness of pair programming in developing students' computational thinking skills through Scratch. *Proceedings of International Conference on Computational Thinking Education*, 2–7.
- Li, X., Li, J., & Li, J. (2021). Cultivating computational thinking through game-based Scratch programming. *Proceedings of International Conference on Computational Thinking Education*, 14–17.
- Marchisio, M., Roman, F., & Sacchet, M. (2021). Basic mathematical modelling competencies for non-stem higher education. *15th International Conference E-Learning, EL 2021 - Held at the 15th Multi-Conference on Computer Science and Information Systems, MCCSIS 2021*, 54–61.
- Marini, A., Handayani, T. P., Yarmi, G., Safitri, D., Dewiyani, L., & Zahari, M. (2026). Game on! Scratch-based interactive multimedia to boost math success in fourth grade. In N. Ishartono & Y. Sidiq (Eds.), *AIP Conference Proceedings* (Vol. 3412, Number 1). American Institute of Physics. <https://doi.org/10.1063/5.0318641>
- Masamah, L., & Murtiyasa, B. (2025). Description of the use of interactive multimedia as a medium for learning flat-sided mathematics. In I. N. & W. M.

- (Eds.), *AIP Conference Proceedings* (Vol. 3333, Number 1). American Institute of Physics. <https://doi.org/10.1063/5.0290422>
- Medeiros, R. N. D., Naia, M. D., & Lopes, J. B. (2024). PhET interactive simulations in physics teaching practices: a meta-analysis. *Revista Brasileira de Ensino de Física*, 46. <https://doi.org/10.1590/1806-9126-RBEF-2024-0186>
- Ming, C. H., Adenan, N. H., Karim, N. S. A., Yahya, F. H., Rajoo, M., & Majid, F. A. (2023). Development and usability of SLEQ kit topic of linear equation. *Journal of Science and Mathematics Letters*, 11(Special Issue), 45–52. <https://doi.org/10.37134/jsml.vol11.sp.5.2023>
- Mwei, P. K. (2017). Problem solving: How do in-service secondary school teachers of mathematics make sense of a non-routine problem context? *International Journal of Research in Education and Science*, 3(1), 31–41. <https://doi.org/10.21890/ijres.267368>
- Naamaoui, Y., Chergui, M., & El Wahbi, B. (2024). Attitudes on modelling difficulties with differential equations. *International Journal on Technical and Physical Problems of Engineering*, 16(3), 62–70.
- Nandyansah, W., Suprpto, N., & Mubarak, H. (2020). Picsar (physics augmented reality) as a learning media to practice abstract thinking skills in atomic model. *Journal of Physics: Conference Series*, 1491(1). <https://doi.org/10.1088/1742-6596/1491/1/012049>
- Ndiung, S., Jehadus, E., & Apsari, R. A. (2021). The effect of treffinger creative learning model with the use of RME principles on creative thinking skill and mathematics learning outcome. *International Journal of Instruction*, 14(2), 873–888. <https://doi.org/10.29333/iji.2021.14249a>
- Plothová, L., Páleníková, K., Naštická, Z., Florková, M., & Šubová, L. (2017). An analysis of students' use of mathematical models in solving tasks with real-life context. In S. D., R. D., L. P., & P. M. (Eds.), *16th Conference on Applied Mathematics, APLIMAT 2017 - Proceedings* (pp. 1207–1223). Slovak University of Technology in Bratislava.
- Pólya, G. (1945). *How to Solve It: A New Aspect of Mathematical Method*. Princeton University Press.
- Possumah, B. V., & Qohar, A. (2024a). Development of interactive multimedia-based learning media assisted by Adobe Flash Professional CS6 on the topic of measures of central tendency. In R. D., U. A.D., R. I., P. A.D., A. L.W., S. M., & S. R.F. (Eds.), *AIP Conference Proceedings* (Vol. 3235, Number 1). American Institute of Physics. <https://doi.org/10.1063/5.0234289>
- Possumah, B. V., & Qohar, A. (2024b). Development of interactive multimedia-based learning media assisted by Adobe Flash Professional CS6 on the topic of measures of central tendency. In D. Rahmadani, A. D. Utami, I. Rofiki, A. D. Pahrany, L. W. Aeli, M. Solikhin, & R. F. Suwarman (Eds.), *AIP Conference Proceedings* (Vol. 3235, Number 1). American Institute of Physics. <https://doi.org/10.1063/5.0234289>
- Pujiastuti, E., & Pambudi, M. (2025). Promoting mathematics problem-solving ability in gamification integration using augmented reality. *European Journal of Educational Research*, 14(2), 645–660. <https://doi.org/10.12973/eu-jer.14.2.645>
- Putra, I. S., Masriyah, M., & Sulaiman, R. (2018). Students' translation ability of mathematical representations (symbolic and visual) based on their learning styles.

- In W. S.C., F. S., R. Y.S., S. N., E. R., N. A.B.D., & J. M. (Eds.), *Journal of Physics: Conference Series* (Vol. 1108, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1108/1/012079>
- Reinke, L. T. (2019). Toward an analytical framework for contextual problem-based mathematics instruction. *Mathematical Thinking and Learning*, 21(4), 265–284. <https://doi.org/10.1080/10986065.2019.1576004>
- Riyadi, S., Qamar, K., Wulandari, T. C., & Oktaviana, I. (2019). Mathematical connection: How is student's ability to complete a two-variable linear equation system? *Journal of Physics: Conference Series*, 1321(3). <https://doi.org/10.1088/1742-6596/1321/3/032001>
- Riyat, M. K., Kakkar, R. K., & Kakkar, A. (2025). Creating immersive learning experiences in education domain through virtual and augmented reality. In *Enhancing Learning Experiences With Digital Tools: AI, ChatGPT, and Virtual and Augmented Reality* (pp. 123–155). IGI Global. <https://doi.org/10.4018/979-8-3693-9811-1.ch006>
- Safitri, D., Awalia, S., Sekaringtyas, T., Nuraini, S., Lestari, I., Suntari, Y., Marini, A., Iskandar, R., & Sudrajat, A. (2022). Improvement of student learning motivation through word-wall-based digital game media. *International Journal of Interactive Mobile Technologies*, 16(6), 188–205. <https://doi.org/10.3991/ijim.v16i06.25729>
- Santoso, T., Nafis, H. L. H., & Oktama, M. Y. (2019). Analyzing students' error in problem solving of two-variable linear equation system: A case study of grade eight students of Indonesian junior high school. *International Journal of Learning, Teaching and Educational Research*, 18(11), 283–296. <https://doi.org/10.26803/ijlter.18.11.17>
- Sari, M. R., & Qohar, A. (2023). Development of mathematics learning media based on Articulate Storyline 3 on cube materials. In S. null, K. Shimizu, E. Cahyono, M. null, C. P. Lim, & S. Aazmi (Eds.), *AIP Conference Proceedings* (Vol. 2614). American Institute of Physics, Inc. <https://doi.org/10.1063/5.0125871>
- Sari, S., Elniati, S., Martin, S. N., & Rusyda, N. A. (2024). Game-based learning approach on students' motivation in mathematics learning: A systematic review of literature. In Y. null, R. P.C., W. G.K., S. D.P., T. F., R. R., & R. N.A. (Eds.), *AIP Conference Proceedings* (Vol. 3024, Number 1). American Institute of Physics. <https://doi.org/10.1063/5.0204414>
- Shtayyat, A., & Gawanmeh, A. (2025). Gamification and AI for enhanced student engagement and automated assessment in higher education Moodle e-learning. *2025 16th International Conference on Information and Communication Systems, ICICS 2025*. <https://doi.org/10.1109/ICICS65354.2025.11073106>
- Solikhatun, I., & Sari, R. C. (2023). Sharia financial education using augmented reality technology to increase student motivation in distance learning. In T. Yokozeeki, G. N. C. Santos, R. C. Omar, W. Null, A. C. Tristan, R. F. Putri, & I. W. Mustika (Eds.), *AIP Conference Proceedings* (Vol. 2654). American Institute of Physics Inc. <https://doi.org/10.1063/5.0114754>
- Soneira, C., González-Calero, J. A., & Arnau, D. (2023). Effect of algebraic language and problem text wording on problem model accuracy when solving age word problems. *Educational Studies in Mathematics*, 114(1), 109–127. <https://doi.org/10.1007/>

- s10649-023-10236-x
- Srikanth Reddy, E., Kumar, J. P., Kumar, S. A., Purushothaman, D., Sajjan, V., & Hota, C. P. P. K. (2024). Next-gen classrooms: augmented and virtual reality in modern education. *ICCDS 2024 - International Conference on Computing and Data Science*. <https://doi.org/10.1109/ICCDS60734.2024.10560399>
- Strijbol, N., De Proft, R., Goethals, K., Mesuere, B., Dawyndt, P., & Scholliers, C. (2024). Blink: An educational software debugger for Scratch. *SoftwareX*, 25. <https://doi.org/10.1016/j.softx.2023.101617>
- Susilawati, W., Maryono, I., & Maimunah, S. (2018). The development of Adobe Flash-based interactive multimedia to enhance students' mathematical communication skills. In N. A. B. D. & A. A. G. (Eds.), *IOP Conference Series: Materials Science and Engineering* (Vol. 434, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1757-899X/434/1/012011>
- Talpur, N., Aziz, N., Khatoon, S., Abdullah, M. H. A., & Balogun, A. O. (2024). The gamification effect of simplifying complex mathematics and statistics concepts: a case study of online game-based quiz tools. *2024 International Conference on TVET Excellence and Development, ICTeD 2024*, 130–135. <https://doi.org/10.1109/ICTeD62334.2024.10844627>
- Torralba, K. D., & Doo, L. (2020). Active learning strategies to improve progression from knowledge to action. *Rheumatic Disease Clinics of North America*, 46(1), 1–19. <https://doi.org/10.1016/j.rdc.2019.09.001>
- Torres-Peña, R. C., Peña-González, D., Lara-Orozco, J. L., Ariza, E. A., & Vergara, D. (2025). Enhancing numerical thinking through problem solving: a teaching experience for third-grade mathematics. *Education Sciences*, 15(6). <https://doi.org/10.3390/educsci15060667>
- Utaminingsih, S., Amalia, I., & Sumaji, S. (2024). Management of mathematics learning based on interactive digital worksheets to improve students' critical thinking ability. *Journal of Curriculum and Teaching*, 13(1), 159–169. <https://doi.org/10.5430/jct.v13n1p159>
- Vidad, D. C., & Quimbo, M. A. T. (2021). Students' problem-solving difficulties and coping strategies in mathematics: A model-building study. *International Journal of Learning, Teaching and Educational Research*, 20(9), 136–173. <https://doi.org/10.26803/ijlter.20.9.9>
- Wahid, A. H., Rahman, K., Qodriyah, K., El Iq Bali, M. M., Baharun, H., & Muali, C. (2020). Effectiveness of Android-based mathematics learning media application on student learning achievement. In R. Null, I. I., Y. Y., K. null, A. Z., & R. R. (Eds.), *Journal of Physics: Conference Series* (Vol. 1594, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1594/1/012047>
- Wang, Y., Zhang, G.-W., & Wang, G.-X. (2025). Integrate visual programming into early algebra learning: analysis of reconstruction of algebraic thinking. *International Journal of Science and Mathematics Education*, 23(8), 3929–3951. <https://doi.org/10.1007/s10763-025-10613-3>
- Wati, S., & Fitriana, L. (2018). Students' difficulties in solving linear equation problems. *Journal of Physics: Conference Series*, 983(1). <https://doi.org/10.1088/1742-6596/983/1/012137>
- Wen, F.-H., Wu, T., & Hsu, W.-C. (2023). Students learning performance and engagement in a visual programming

- environment. In H. Y.-M. & T. Rocha (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): 14099 LNCS* (pp. 120–129). Springer science and business media deutschland GmbH. https://doi.org/10.1007/978-3-031-40113-8_12
- Widiatsih, A., Baehaqi, I., & Ariyanto, D. (2020). Mathematics interactive CD media based on discovery learning on congruence material and its effect on the students' generalization thinking skills. In W. D. (Ed.), *Journal of Physics: Conference Series* (Vol. 1465, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1465/1/012040>
- Widoyoko, E. P. (2018). *Teknik Penyusunan Instrumen Penelitian*. Pustaka Pelajar.
- Widyastuti, E. (2019). Using the ADDIE model to develop learning material for actuarial mathematics. In P. P.W. & JI. R. S. Universitas Ahmad Dahlan Kampus IV (UAD) Kragilan, Tamanan, Banguntapan, Bantul, Daerah Istimewa Yogyakarta (Eds.), *Journal of Physics: Conference Series* (Vol. 1188, Number 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1188/1/012052>
- Yadav, S. (2025). Transformative learning with advanced technologies: Harnessing VR and AR for immersive educational experiences. In *Revolutionizing Pedagogy Through Smart Education* (pp. 139–155). IGI Global. <https://doi.org/10.4018/979-8-3693-7793-2.ch008>
- Yang, H., Li, Y., Liang, Z., Chen, H., Chen, M., & Zhang, X. (2025). Design and application of high school Scratch programming instructional activities for computational thinking development. *2025 7th International Conference on Computer Science and Technologies in Education, CSTE 2025*, 112–116. <https://doi.org/10.1109/CSTE64638.2025.11092227>
- Yesmambetova, K. N. (2019). Students' lack of interest: How to motivate them? *Universal Journal of Educational Research*, 7(3), 797–802. <https://doi.org/10.13189/ujer.2019.070320>
- Yesseikyzy, A., Smagulov, Y., Aldabergenova, A., & Ualiev, N. (2025). The impact of digital educational resources on enhancing logical thinking skills of future mathematics teachers. *Global Journal of Engineering Education*, 27(1), 6–15.
- Yousuf, B., & Conlan, O. (2020). Assessing the impact of controllable open learner models on student engagement. In M. Chang, D. G. Sampson, R. Huang, D. Hooshyar, C. N.-S., K. Kinshuk, & M. Pedaste (Eds.), *Proceedings - IEEE 20th International Conference on Advanced Learning Technologies, ICALT 2020* (pp. 47–49). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ICALT49669.2020.00021>
- Zamnah, L. N. (2021). Make questions as a stimulus for students to help them carry out their Polya's in solving problems. *Journal of Physics: Conference Series*, 1918(4). <https://doi.org/10.1088/1742-6596/1918/4/042099>
- Zhou, S., & Yang, S. (2024). The advantages of introducing multimedia technology into college students' physical education. In Z. Y. & S. N. (Eds.), *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST: 584 LNICST* (pp. 61–71). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-63142-9_6