

Development of macromedia flash-based mathematics media integrated with discovery learning to improve students' problem-solving ability

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Abstract

This study aimed to develop Macromedia Flash-based learning media integrated with a discovery learning approach and to evaluate its validity, practicality, and effectiveness in enhancing students' mathematical problem-solving skills. The research employed a research and development (R&D) design using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The participants were 60 Grade X students from SMA Negeri 5 Medan, comprising 30 students in Trial I (Class X MIPA 4) and 30 students in Trial II (Class X MIPA 9). Data were collected through expert validation sheets, classroom observations, mathematical problem-solving tests, and student response questionnaires. The results showed that the developed learning media achieved a high level of validity, indicated by an overall expert evaluation score of 3.71. The media also demonstrated strong practicality, supported by positive classroom implementation and student responses, with the average response score increasing from 3.54 in Trial I to 3.64 in Trial II. Regarding effectiveness, students' mathematical problem-solving abilities improved, as evidenced by an *N*-gain of 0.21 (low) in Trial I and 0.34 (medium) in Trial II. Furthermore, classical mastery increased from 54% in Trial I to 90% in Trial II, and learning objective achievement across three indicators improved from 67.1%, 69.8%, and 65% in Trial I to 79%, 79.8%, and 75.5% in Trial II, respectively. Overall, the findings indicate that Macromedia Flash-based learning media integrated with discovery learning is a valid, practical, and effective instructional tool for improving students' mathematical problem-solving abilities.

Keywords: Discovery Learning Model; Macromedia Flash; Problem-Solving Ability

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INTRODUCTION

Education is essential for developing competent and competitive human resources. Among school subjects, mathematics supports students' conceptual understanding and skills in thinking, reasoning, communication, and problem-solving (Branca, 1980). However, empirical findings and initial observations suggest that senior high school students' mathematical problem-solving abilities remain relatively low. Students often struggle to interpret problem information, identify what is known and required, construct mathematical models, and choose appropriate solution strategies. Prior studies also highlight the need to improve these abilities through suitable instructional approaches

(Siregar, 2025; Faoziyah et al., 2024; Elfira & Syarifudin, 2022). These difficulties may stem from low motivation to learn, teacher-centered instruction, and limited learning media that support visualization and conceptual understanding.

To address these issues, learning activities should actively involve students in exploring, investigating, and constructing mathematical knowledge. Discovery learning is considered suitable because it encourages students to discover concepts through exploration, reasoning, and investigation, thereby enhancing problem-solving skills (McDaniel & Schlager, 1990; Surur & Oktavia, 2019). Evidence shows that discovery learning improves students' mathematical problem-solving abilities (Pramaeda et al., 2020), supports their confidence (Faoziyah et al., 2024), and contributes to students' understanding of mathematical concepts (Surur & Oktavia, 2019; Wulandari & Tasriyah, 2024). Despite these positive findings, several limitations remain. First, many studies do not clearly detail the role of interactive instructional media in guiding students through the phases of problem solving. Second, some studies focus mainly on content presentation without evaluating learning media comprehensively using development criteria such as validity, practicality, and effectiveness. Third, existing media often rely on newer technological conditions (stable internet, high-spec devices, advanced platforms) that may not be feasible in all school contexts. Therefore, learning media should align with discovery learning and be demonstrably valid, practical, and effective in realistic classroom settings.

The effectiveness of discovery learning can be strengthened through interactive instructional media. Prior research has shown that Macromedia Flash and Adobe Flash-based interactive multimedia can support students' conceptual understanding, learning outcomes, and mathematical problem-solving abilities (Siregar & Hasratuddin, 2022; Hamzari et al., 2024), learning motivation (Maghfiroh et al., 2024), and visual thinking (Atika et al., 2022). Similar findings have been reported in other subjects, indicating that Flash-based interactive media can enhance understanding and engagement (Azizaturrizkina et al., 2021; Hanafi et al., 2024). Although Flash is often considered outdated, this study selected Flash for practical reasons: playback is still supported in the school environment, students access the media via school computers, and mobile phone access is limited despite available internet. In addition, the research team has limited time and capacity to develop alternative media such as HTML5 modules or mobile

applications. Thus, Flash was chosen not to claim superiority over modern platforms, but to provide an implementable interactive learning environment that was evaluated against development criteria aligned with the discovery learning phases.

Based on this discussion, the integration of Flash-based interactive media with discovery learning, particularly regarding its measurable validity, practicality, and effectiveness, remains insufficiently explored. While previous studies have examined discovery learning to improve mathematical problem-solving (Siregar, 2025) and Flash-based media in mathematics learning (Sari et al., 2022), further investigation is needed into integrating both components within an ADDIE-based development process, a method proven to yield highly practical and systematically structured learning tools (Khawarizmi et al., 2024). Therefore, this study aims to develop Macromedia Flash-based mathematics learning media integrated with the discovery learning model using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, and to examine its validity, practicality, and effectiveness in improving students' mathematical problem-solving abilities.

METHODS

This study used a research and development (R&D) approach, employing the ADDIE model, to develop and evaluate Macromedia Flash-based mathematics learning media integrated with the Discovery Learning model. ADDIE was selected because it provides systematic stages for analyzing needs, designing learning products, developing and validating products, implementing them, and conducting evaluation (Arikunto, 2012; Sugiyono, 2019; Siregar & Rhamayanti, 2025).

Effectiveness was assessed using a one-group pretest–posttest design in Trial I and Trial II. In each trial, students completed a pretest to measure initial mathematical problem-solving ability, received instruction using the developed media aligned with Discovery Learning phases, and then completed a posttest. Learning improvement was analyzed using N-Gain and other effectiveness indicators.

Participants were 60 Grade X students from SMA Negeri 5 Medan (2022/2023) in the MIPA track, with 30 students in Trial I (Class X MIPA 4) and 30 in Trial II (Class X MIPA 9). The sample was selected using purposive non-probability sampling, based on the availability of intact classes for implementation and their suitability for the targeted

topic during the study period. Content validity of the learning materials and instruments was obtained through expert judgment by five experts, whose scores were analyzed to produce overall mean ratings used for revisions throughout the ADDIE process.

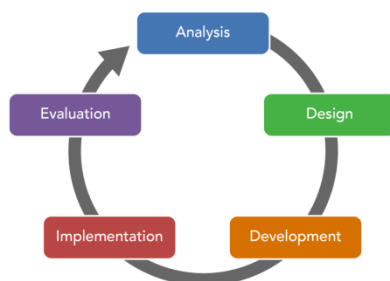


Figure 1. Research Steps Using the ADDIE Model (Branch, 2010)

RESULTS AND DISCUSSION

1. Analysis

Preliminary observations at SMA Negeri 5 Medan indicated that the limited use of mathematics learning media, especially for teaching systems of inequalities in two variables, was associated with students' relatively low mathematical problem-solving abilities. The media used by teachers were not sufficiently engaging or supportive of students' conceptual understanding, and instruction remained largely teacher-centered. Consequently, students were less active and tended to imitate procedures rather than develop their own problem-solving strategies. Similar needs for appropriate learning models and media to improve mathematical problem-solving abilities have been reported in previous studies (Elfira & Syarifudin, 2022). Therefore, it was necessary to develop learning media that are valid, practical, and effective.

Based on an analysis of the school's textbooks, students' needs, and the 2013 Curriculum, systems of inequalities in two variables were selected as the Grade X learning material. Essential concepts were identified and organized into a concept map, which was then adapted into the developed media. The media was designed to be interactive and engaging, using animations and visualizations to support students' understanding of mathematical concepts and problem-solving skills (Hamzari et al., 2024; Sari et al., 2022).

2. Design

The purpose of this stage was to design the learning media in order to produce a prototype or initial design for the topic of systems of inequalities in two variables. Several

activities were carried out during this stage, including: (1) developing storyboards, (2) organizing the learning materials, (3) preparing lesson plans, and (4) designing student worksheets.

3. Development

The development stage is the process of transforming the initial design into a completed product. To achieve the intended learning objectives, this stage involved designing and modifying Macromedia Flash-based learning media. The purpose of the development stage was to produce mathematics learning tools that were revised based on suggestions from experts (validators) and trial data. This stage consisted of two main activities, namely expert assessment and product trials. The main activity conducted during this phase was the validation of the developed learning tools. This procedure is consistent with the systematic stages of development in the ADDIE model (Rohaeni, 2020).

4. Implementation

The design stage produced Draft I of the learning media. Before conducting field trials, the Draft experts validated it through a content review covering all learning media components developed during the Draft I stage. The expert evaluation generated Draft II, which was considered suitable for implementation. The validation results served as the basis for revising and improving both the learning media and the research instruments. The aspects evaluated during validation included content quality and objectives, learning and instructional strategies, and media design.

5. Evaluation

Effectiveness was judged through: (1) problem-solving test results, (2) achievement of learning objectives, (3) learning time efficiency, and (4) students' responses. Based on Trial I and Trial II, the developed media met validity and practicality criteria and showed improved learning outcomes. Students' problem-solving ability improved from N-Gain = 0.21 (low) in Trial I to N-Gain = 0.34 (medium) in Trial II. Learning objective achievement (three items/LOs) increased from not meeting the criterion in Trial I to meeting it in Trial II, while classical mastery increased from 54% to 90%.

Table 1. Comparison of Trial I and Trial II Outcomes

Indicator	Trial I	Trial II
N-Gain	0.21 (Low)	0.34 (Medium)
Learning objective achievement (Item/LO 1)	67.1%	79%
Learning objective achievement (Item/LO 2)	69.8%	79.8%
Learning objective achievement (Item/LO 3)	65%	75.5%
Classical mastery	54%	90%

5.1 The Validity of Learning Devices Developed

The validity test was conducted to identify weaknesses in the initial draft of the learning tools, particularly in basic competencies, learning materials, sample questions, and practice exercises, all aligned with the needs of Grade X at SMA Negeri 5 Medan. Validation involved five experts. The overall average score was 3.71, which falls in the "Valid" category. Validators stated that the developed media was suitable for use after several revisions. Expert validation and revision align with ADDIE procedures, in which evaluation and revision are essential to improve the quality of the learning product (Rohaeni, 2020; Siregar & Rhamayanti, 2025).

This result aligns with Nasution *et al.* (2025), who describe validity as comprising content and construct validity. Content validity reflects alignment with curriculum requirements (KI, KD, and learning materials), whereas construct validity reflects consistency with the concepts and indicators of students' mathematical problem-solving abilities. The learning tools developed, Macromedia Flash, lesson plans (RPP), and student worksheets (LKPD), were prepared according to these requirements. Akbar (2013) further notes that media validated by experts and meeting validity criteria are appropriate for implementation. Recent evaluations of interactive media development also emphasize that expert validation of content, interface, and instructional design is a crucial prerequisite for ensuring the practicality of the media during empirical field testing (Khawarizmi et al., 2024). Therefore, the Macromedia Flash-based learning media, developed and integrated with the discovery learning model, met the required validity criteria.

5.2 Improvement of Problem-Solving Ability After Using Macromedia Flash Based on Discovery Learning

Students' problem-solving abilities improved after using the developed learning media. In Trial I, the average score increased from 59.38 to 72.92, though N-Gain

remained low ($N\text{-Gain} = 0.21$). After revisions, especially the addition of more structured practice, students' performance improved further in Trial II, with scores rising from 65.63 to 79.17 and $N\text{-Gain}$ increasing to 0.34 (medium). This improvement aligns with prior findings that Discovery Learning supports students' mathematical problem-solving abilities (Siregar, 2025) and that it demonstrates measurable cognitive gains when effectively supported by digital instructional media (Pramaeda & Ningsih, 2020). The improvement mainly occurred because Discovery Learning positions students as active problem solvers through inquiry phases: (i) understanding the problem by identifying known and required information, (ii) seeking and organizing information/strategies to interpret relationships between variables, (iii) constructing mathematical representations/models for systems of inequalities, and (iv) verifying and concluding by checking the correctness of reasoning. These phases repeatedly train key cognitive steps in problem solving, helping students develop reasoning processes (modeling, strategy selection, verification), not only final procedures. This is consistent with McDaniel and Schlager (1990), who linked discovery learning with the transfer of problem-solving skills.

Macromedia Flash-based media strengthened these phases through interactive animations and visualizations, step-by-step guided prompts aligned with inquiry stages, structured section-wise tasks that enabled repeated practice, and immediate feedback/support embedded in the learning flow. This explains why the added practice after Trial I contributed to the higher $N\text{-Gain}$ in Trial II.

Learning activities also became more student-centered. In Trial I, students were generally less active and tended to imitate solution procedures for unfamiliar structures. In Trial II, students were more engaged: they first attempted to interpret the problem, discussed possible strategies, used the media's visual representations to support their modeling, and checked answers during verification rather than only submitting final results. This increased reasoning-based participation supports the observed performance gains. Thus, the higher $N\text{-Gain}$ from Trial I to Trial II can be understood as the combined effect of Discovery Learning's inquiry process and the Flash media's interactive supports that operationalized those inquiry steps and strengthened students' practice.

5.3 The Effectiveness of Macromedia Flash Based on the Developed Discovery Learning Model

The effectiveness of the developed Macromedia Flash-based learning media integrated with Discovery Learning was evaluated using N-Gain, learning objective achievement, classical mastery, learning time efficiency, and students' responses. Students' problem-solving abilities improved from N-Gain = 0.21 (low) in Trial I to N-Gain = 0.34 (medium) in Trial II. Learning objective achievement increased from not meeting the criterion in Trial I to meeting it in Trial II (item-wise achievement: 67.1%, 69.8%, 65% → 79%, 79.8%, 75.5%). Classical mastery rose from 54% in Trial I to 90% in Trial II, showing that students reached the expected mastery level after product revision. These results align with prior studies that interactive multimedia and Macromedia Flash-based media improve learning outcomes, conceptual understanding, and mathematical problem-solving abilities (Sari et al., 2022).

These effectiveness findings are also supported by the learning process. Discovery Learning organized students' activities into reasoning-oriented phases, while Macromedia Flash supported each phase through interactive visualizations, guided prompts, and practice reinforcement. As a result, students became more active in inquiry and verification, leading to deeper understanding and more complete problem-solving strategies.

5.3.1 Achievement of Learning Objectives

Learning objective achievement was determined by students' mastery of each learning objective, assessed through three corresponding test items. A learning objective was considered achieved when more than 75% of students were categorized as mastering on each respective item. In Trial I, learning objective achievement was not yet reached because each item still showed values below the criterion: 67.1%, 69.8%, and 65%. Therefore, none of the learning objectives was fully attained in Trial I. After revisions and implementation in Trial II, learning objective achievement increased and met the criterion for all items: 79%, 79.8%, and 75.5%. This indicates that the developed learning media effectively supported students in achieving the intended learning objectives.

5.3.2 Classical Student Learning Completeness

Classical mastery in Trial I reached 57% (17 students achieving mastery), indicating that the developed Macromedia Flash-based learning media had not yet met

the required classical mastery criterion of more than 85%. After revisions, Trial II showed a substantial improvement, with 90% of students (27 students) achieving mastery. This means that the developed learning media met the effectiveness criteria in terms of students' mastery of mathematical problem-solving abilities. The improvement is consistent with previous findings indicating that interactive multimedia and Flash-based learning media can support students' learning outcomes and understanding (Sari *et al.*, 2022; Nasution *et al.*, 2025). The improvement can also be explained through Vygotsky's scaffolding theory, which aligns with the Discovery Learning model. Through interactions among students, teachers, and learning media, students receive appropriate support to construct understanding. Teachers provide guidance through questions, directions, or suggestions as needed, then gradually reduce assistance as students become more capable of solving problems independently.

5.3.3 Time Use

Under the 2013 Curriculum, weekly study hours at SMA/MA level were increased, with each lesson hour lasting 45 minutes. In this study, the implementation of the Macromedia Flash-based learning media, integrated with Discovery Learning, did not exceed the instructional time allocated in the syllabus for systems of inequalities in two variables (6×45 minutes). Therefore, the learning activities were considered efficient and completed within the expected timeframe.

5.3.4 Student Response

Students' responses were positive in both Trials I and II. The average response score increased from 3.54 in Trial I to 3.64 in Trial II, with both categorized as "interested." These results indicate that the Macromedia Flash-based learning media, integrated with Discovery Learning, was effective at attracting students' interest. Yunus *et al.* (2021) also reported that students responded very positively to Macromedia Flash-based learning media and showed greater motivation and persistence in understanding learning materials. This suggests that the developed media not only improved learning outcomes but also enhanced students' engagement in learning.

CONCLUSION

This study successfully developed and evaluated Macromedia Flash-based mathematics learning media integrated with discovery learning for teaching systems of

inequalities in two variables to Grade X students. The ADDIE-based development process yielded a highly valid product (expert validation score of 3.71), practical (positive student response scores increasing from 3.54 to 3.64), and effective. The media significantly enhanced students' mathematical problem-solving abilities, as evidenced by an increase in N-gain from 0.21 in Trial I to 0.34 in Trial II, along with a substantial rise in classical mastery from 54% to 90%. From a practical standpoint, this media provides teachers with an interactive tool to facilitate discovery learning, effectively guiding students through the critical stages of problem interpretation, modeling, reasoning, and verification.

Despite these positive outcomes, the study has several limitations. The research was confined to a single school, had a relatively small sample size, and focused strictly on a specific mathematical topic. Additionally, the reliance on Macromedia Flash, while practically justified for the specific school context, involves using a legacy technology platform that may not be sustainable or compatible with modern web and mobile ecosystems in other educational settings. To address these limitations, future research should implement this instructional design across a broader range of schools, grade levels, and mathematical topics to test generalizability. Furthermore, future studies are encouraged to adapt the pedagogical principles and interactive features developed in this study into more modern, cross-platform technologies (e.g., HTML5 or mobile applications) to ensure long-term accessibility and evaluate their impact on student learning outcomes over extended periods.

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