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Development of Scratch-Based Mathematics Learning Media on Algebra

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ABSTRACT This study aimed to develop Scratch-based mathematics learning media entitled SpongeBob Squad in Algebra Wonderland and describe initial users' responses to the media. The product was developed using the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collecting, assembly, testing, and distribution. The initial trial involved 18 third-semester pre-service mathematics teachers selected through convenience sampling at a university in Bandung. Data were collected using an open-ended questionnaire and semi-structured interviews and were analyzed through thematic coding and percentages of positive responses. The results showed that the algebra learning game was successfully developed through all MDLC stages. The participants gave an average positive response of 99%, categorized as very good. The appearance indicator received 94% positive responses, while programming, material, language, interest, and usefulness each received 100%. These findings indicate that the prototype received very favorable initial evaluations and was considered engaging, easy to operate, conceptually relevant, and useful for mathematics learning. However, trials involving junior high school students and classroom-based effectiveness studies are still required before broader implementation.

Keywords: Scratch, multimedia development life cycle, algebra learning, game-based learning, learning media

INTRODUCTION

Mathematics is an important subject at every level of education because it supports problem-solving in everyday life and develops students' cognitive and reasoning skills (Pratiwi and Bernard, 2021). Digital media can also support mathematics learning outcomes when it is designed according to students' needs and the characteristics of the topic (Bagasputera et al., 2023).

Nevertheless, many students perceive mathematics as difficult because it contains abstract concepts and symbols (Audina and Dewi, 2021). Learning barriers are also frequently found across elementary and secondary mathematics topics (Wally et al., 2024).

These difficulties can contribute to mathematics anxiety, which affects cognitive, physical, behavioral, and achievement-related aspects of learning (Jalal, 2020). They have also encouraged the use of instructional interventions, including problem-based approaches, to improve students' mathematics learning outcomes (Isnaniyah et al., 2023). Therefore, mathematics instruction should provide learning experiences that are accessible, engaging, and motivating.

Learning motivation plays an important role in maintaining students' attention and willingness to complete learning activities. Enjoyable and innovative game-based learning can increase students' interest and encourage more positive perceptions of mathematics (Ambarsari et al., 2022). Digital games have also been used to improve mathematics learning outcomes and participation (Dermawan and Ramadhan, 2024). In this context, interactive learning media can provide teachers with an alternative resource for presenting mathematical ideas in a more attractive form.

Scratch is a visual programming platform developed by the Massachusetts Institute of Technology that enables users to create interactive stories, animations, and games. Its visual block-based interface makes it suitable for the development of educational media. Studies have shown that Scratch-based media can support students' interest in mathematics (Chaerunnisa and Bernard, 2021), provide interactive learning experiences at the secondary-school level (Assulamy et al., 2023), and facilitate the design of mathematics games for specific concepts (Nuraeni et al., 2021).

One important topic that can be presented through interactive media is algebra. Algebra forms a foundation for learning more advanced mathematics, but many students still experience difficulty understanding algebraic concepts (Munasiah, 2021). Algebraic problems require students to reason about symbols, relationships, operations, and representations (Suprihatiningsih et al., 2014). These characteristics make algebra particularly suitable for interactive media that can connect symbolic expressions with visual feedback and contextual problems.

Previous studies have developed Scratch-based mathematics media for the area of triangles (Sudihartinih et al., 2021a), properties of quadrilaterals (Nuraeni et al., 2021), the greatest common factor (Sudihartinih et al., 2021b), and an adventure-based mathematics game (Lestari and Sudihartinih, 2022). However, limited attention has been given to developing a Scratch game that integrates algebraic elements, like terms, algebraic operations, and contextual problems within one continuous storyline.

To address this gap, the present study developed SpongeBob Squad in Algebra Wonderland, a Scratch-based mathematics game for seventh-grade algebra. The study aimed to describe the development process using the Multimedia Development Life Cycle and analyze initial users' responses to the resulting prototype.

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RESEARCH METHOD

This study used the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collecting, assembly, testing, and distribution (Mustika et al., 2018). The stages are illustrated in Figure 1.

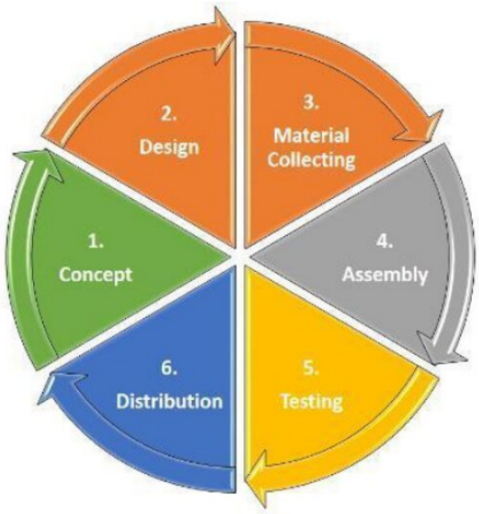

Figure 1. Stages of the Multimedia Development Life Cycle

The product was developed collaboratively by a four-member team over one semester at a university in Bandung. The selected content focused on the application of algebra in everyday life for seventh-grade junior high school students. The game was developed using the online version of Scratch so that team members could construct, review, and revise the program collaboratively.

During the concept stage, the researchers determined the objectives, benefits, intended users, and overall concept of the application. During the design stage, the team prepared the visual and functional specifications, learning sequence, and storyboard. The material-collecting stage involved gathering algebra content, images, backgrounds, animations, and audio. During assembly, these components were integrated into the Scratch project. Testing was conducted iteratively to identify functional or content-related errors. Finally, the completed prototype was stored on Google Drive and the Scratch website during the distribution stage.

The initial user trial involved 18 third-semester pre-service mathematics teachers, consisting of 2 men and 16 women, from a mathematics education program at a university in Bandung. Participants were selected through convenience sampling. Pre-service teachers were chosen as initial evaluators because they possessed relevant algebra knowledge and introductory pedagogical experience. This initial trial was intended to examine the prototype's feasibility before implementation with junior high school students.

Data were collected using an open-ended questionnaire and semi-structured interviews. The questionnaire contained six questions addressing appearance, programming, material, language, interest, and usefulness. These indicators were adapted from previous studies on mathematics learning media and student responses (Chaerunnisa and Bernard, 2021) (Pratama and Waskitoningtyas, 2020). The questions are presented in Table 1.

Table 1. Questionnaire Indicators and Questions

No.	Indicator	Question
1	Appearance	What do you think about the overall appearance of this game?
2	Programming	How easy is it to operate this game?
3	Material	Is the algebra material appropriate, and does it support conceptual understanding?
4	Language	What do you think about the language used in this game?
5	Interest	How did you feel after playing this algebra game?
6	Usefulness	How useful is this game for mathematics learning?

Two participants were selected for follow-up interviews: one whose questionnaire responses were predominantly positive and one who provided the only negative response. This procedure was used to obtain more detailed information about the participants' experiences. Open-ended questionnaire and interview data were analyzed through thematic coding, following the use of qualitative user responses in media-development research (Libryanti et al., 2023). Responses indicating appreciation, ease of navigation, clear instructions, or conceptual alignment were categorized as positive (+), whereas responses indicating confusion, technical problems, or visual dissatisfaction were categorized as negative (−).

The percentage of positive responses was calculated using the following formula:

$$P_+ = \frac{N_+}{N} \times 100\%,$$

where P_+ is the percentage of positive responses, N_+ is the number of positive responses, and N is the number of respondents. The interpretation criteria were adapted from Pratama and Waskitoningtyas (2020) and are presented in Table 2.

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Table 2. Categories of Positive Responses

Percentage (p)	Category
$p > 80$	Very good
$60 < p \leq 80$	Good
$40 < p \leq 60$	Fairly good
$20 < p \leq 40$	Poor
$p \leq 20$	Very poor

RESULTS AND DISCUSSION

Concept

The product was designed as an online mathematics game for seventh-grade junior high school students. Its primary purpose was to provide an enjoyable introduction to algebra and its applications in everyday life. The game was titled SpongeBob Squad in Algebra Wonderland and used a continuous storyline to connect the learning activities. The learning sequence progresses from identifying algebraic elements to classifying like terms, performing operations, and solving contextual problems.

At this stage, the development team also specified the intended learning benefits and the characteristics of the target users. The media was expected to function as a supplementary resource rather than replace classroom instruction. Accordingly, the game was designed to provide short explanations, guided practice, immediate feedback, and a final contextual challenge that could support teacher-led algebra lessons.

The main functional requirements were also established during the concept stage. Users needed to be able to enter their names, move between menus, select learning material, repeat an activity after an incorrect response, and complete the final game independently. These requirements guided the design of the navigation buttons, feedback messages, audio, and scoring rules.

Design

The design stage involved preparing the learning objectives, material sequence, visual specifications, navigation, and storyboard. The opening storyboard is presented in Figure 2.

The storyboard mapped each screen to its visual components, text, animation, audio, and expected user action. It was also used to determine when characters would appear, how users would move to the next screen, and what feedback would be displayed after a correct or incorrect response. Establishing these details before programming reduced inconsistencies during assembly and provided a clear division of tasks among the team members.

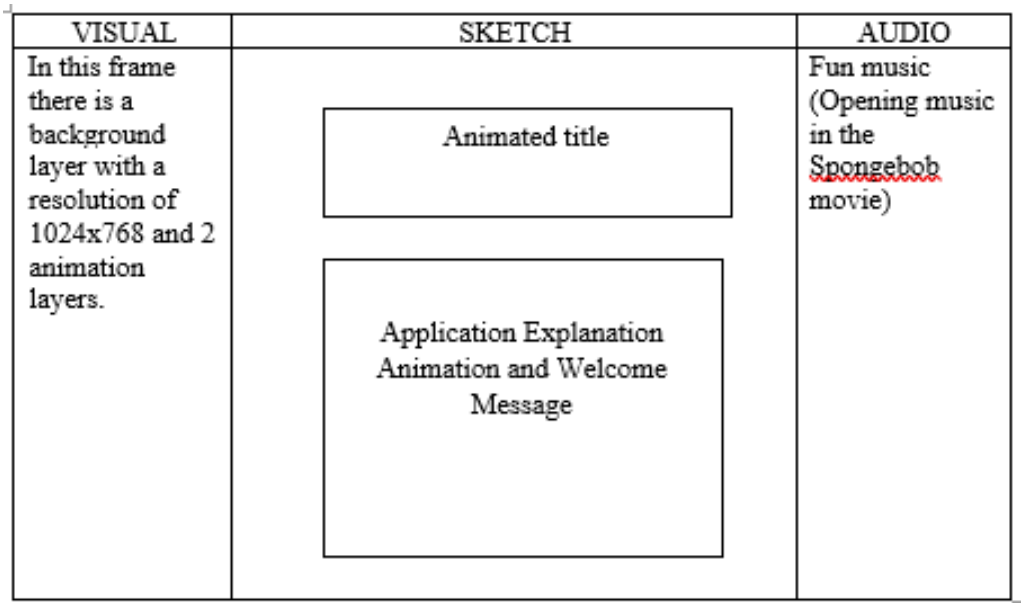

Figure 2. Opening Storyboard

Figure 2 specifies the visual elements, animation, explanatory text, welcome message, and audio used in the opening sequence. This storyboard provided a common reference for the development team and helped maintain consistency between the planned interface and the assembled program.

Material Collecting

The material-collecting stage included gathering algebra content from school textbooks and supporting sources, as well as preparing images, animations, backgrounds, and audio. Canva was used to support visual preparation, while audio was selected to match the storyline and activities. Third-party graphical and audio assets were used only for non-commercial academic prototype testing. For broader public distribution or commercial use, copyrighted characters, backgrounds, and soundtracks should be replaced with original or appropriately licensed assets.

The algebra material was organized into four connected components: identifying variables, coefficients, and constants; recognizing like terms; performing addition and subtraction of algebraic expressions; and applying algebra in contextual problems. This organization ensured that the game moved from foundational concepts to more complex applications. Each visual and audio asset was then matched with the relevant activity so that decorative elements did not obscure the mathematical content.

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Assembly

During assembly, the collected materials were integrated into Scratch according to the storyboard and learning sequence. The resulting product included an opening screen, user-information screen, main menu, algebra learning activities, and a contextual game. The assembly process involved creating sprites and backdrops, arranging visual layers, programming button functions, adding transitions, and synchronizing audio with character movements. Conditional blocks were used to distinguish correct and incorrect responses, while broadcast commands connected one scene to the next. The team repeatedly reviewed these components during assembly to ensure that navigation, feedback, and scoring operated according to the storyboard.

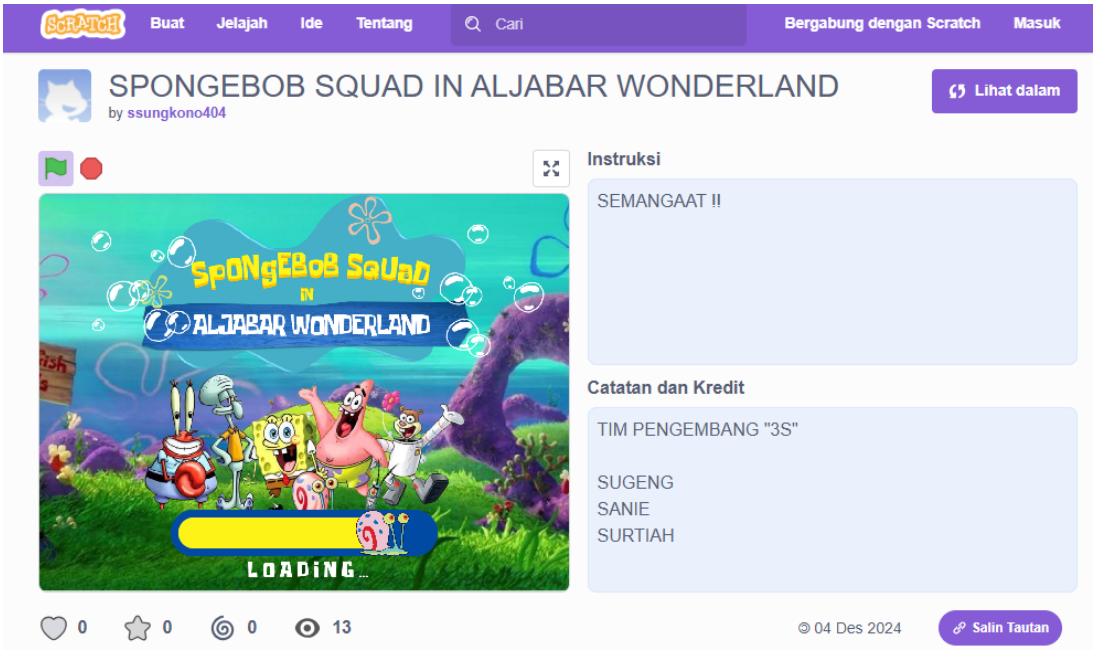

Figure 3. Initial Program Display

Figure 3 shows the opening screen. Users wait for the snail character to finish moving before the next element appears. An “Aye-aye, Captain!” button then allows users to continue to the next screen. This short animated sequence introduces the game setting and prepares users for the interactive activities that follow.

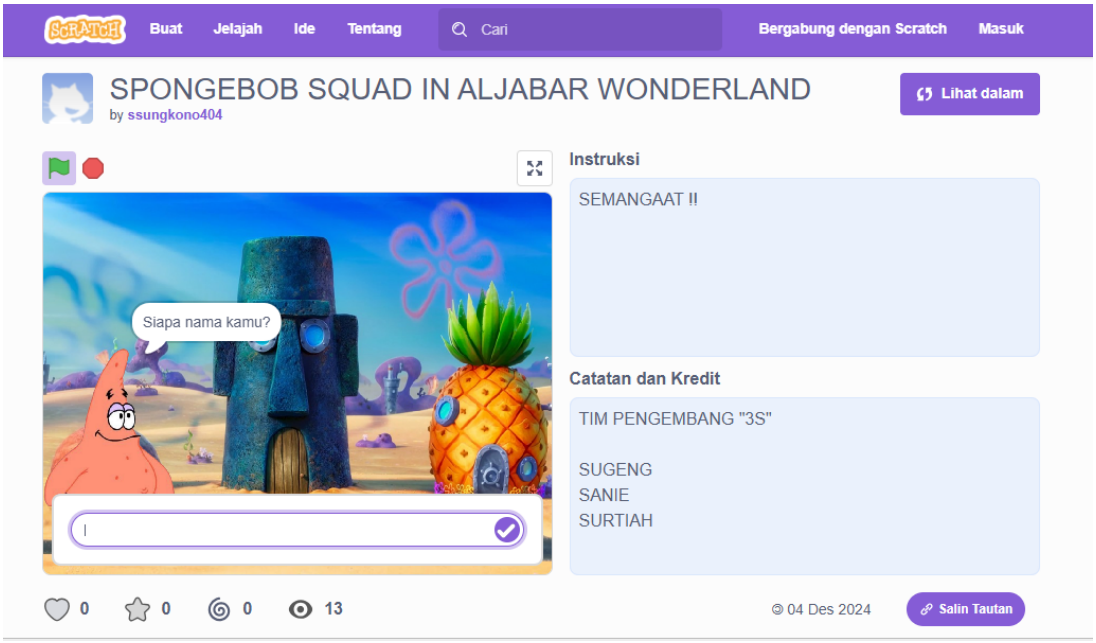

Figure 4. Greeting and User-Information Display

Figure 4 presents the greeting screen and user-information field. The game includes audio and voice instructions to support each question and activity. Collecting the user's name also enables the program to provide a more personalized greeting before the learning sequence begins.

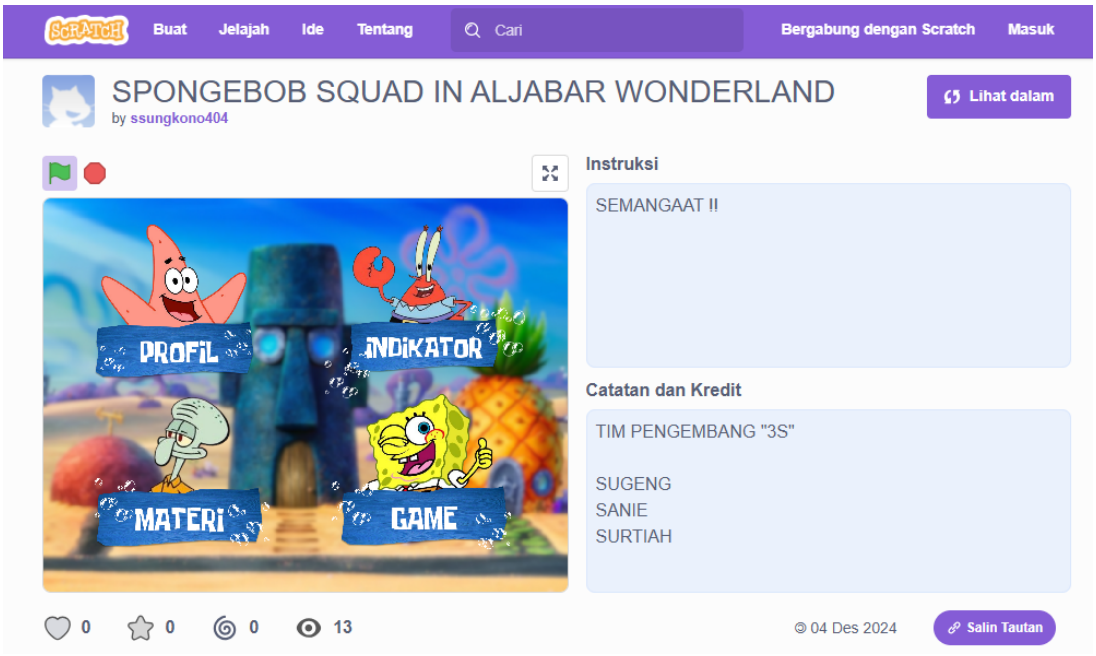

Figure 5. Main Menu Display

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Figure 5 displays the main menu. Users can access the profile, indicators, material, and game menus. The indicators and material are aligned with introductory algebra and its applications in everyday situations. This menu structure separates informational, instructional, and assessment components so that users can navigate the media more easily.

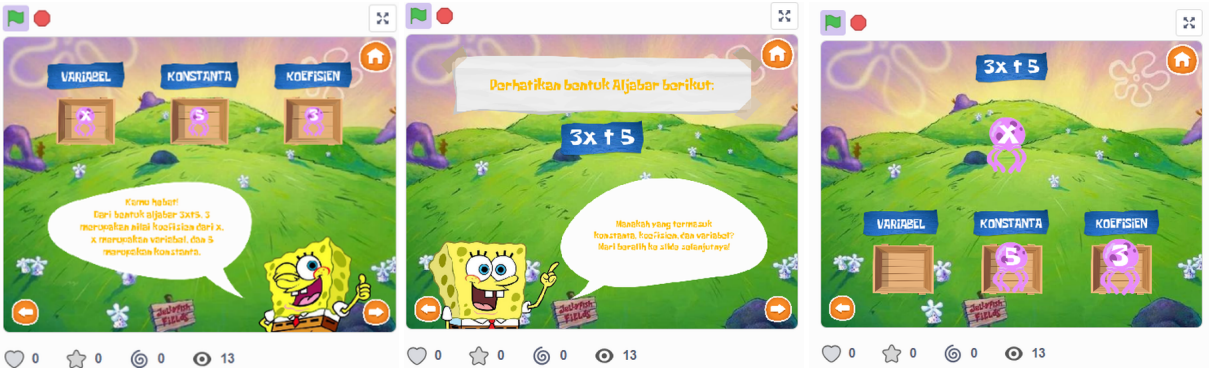

Figure 6. First Algebra Learning Activity

Figure 6 presents an activity designed to review variables, coefficients, and constants. Users drag jellyfish into boxes corresponding to the elements of the given algebraic expression. Correct placements generate positive feedback, whereas incorrect placements are rejected by the program. The drag-and-drop format requires users to classify each algebraic element rather than merely read its definition.

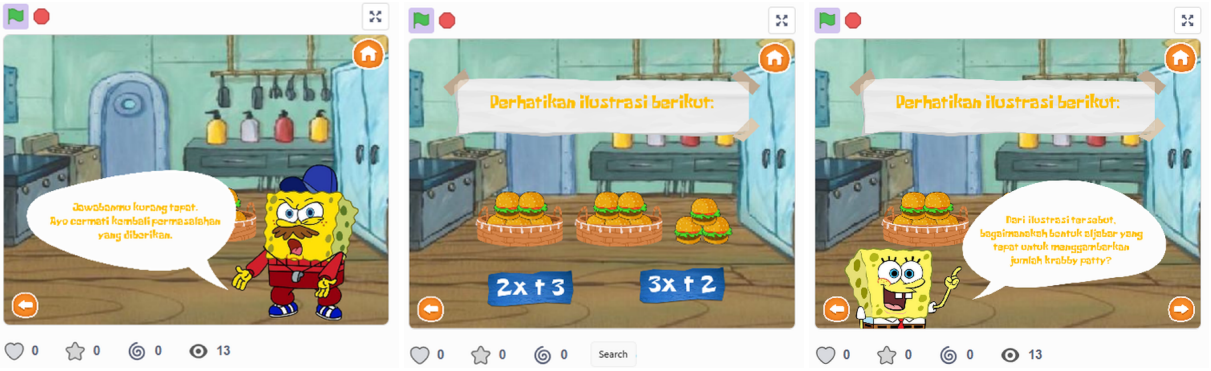

Figure 7. Second Algebra Learning Activity

Figure 7 presents a second activity on variables, coefficients, and constants. Users choose an answer and receive immediate visual and audio feedback. If an incorrect answer is selected, the back button allows the user to return and try again. This opportunity for correction supports repeated engagement with the concept before users proceed to the next activity.

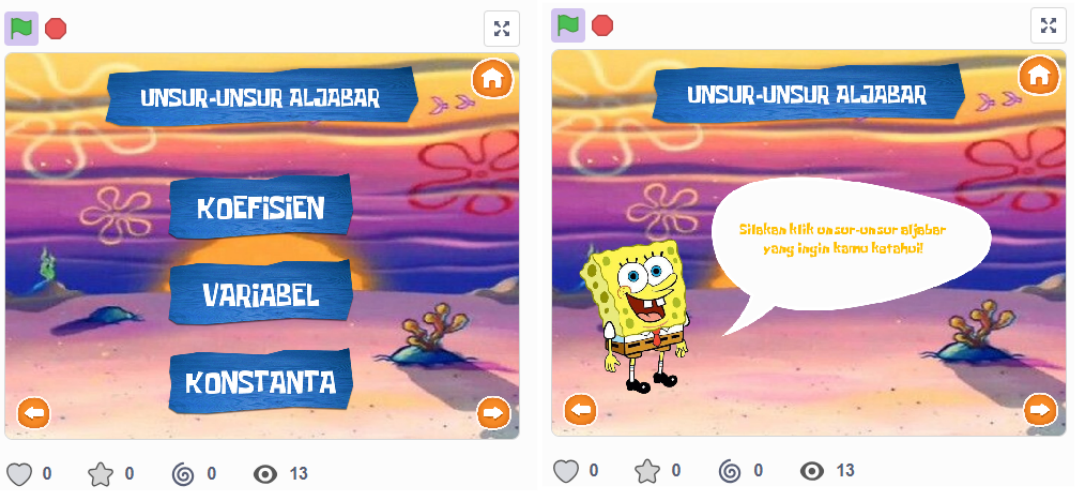

Figure 8. Algebra Element Selection Display

Figure 8 shows a menu through which users can select an algebraic element and view its explanation. Users can continue to the next topic or return to the main menu using the navigation buttons. The selectable menu gives users some control over the order in which they review coefficients, variables, and constants.

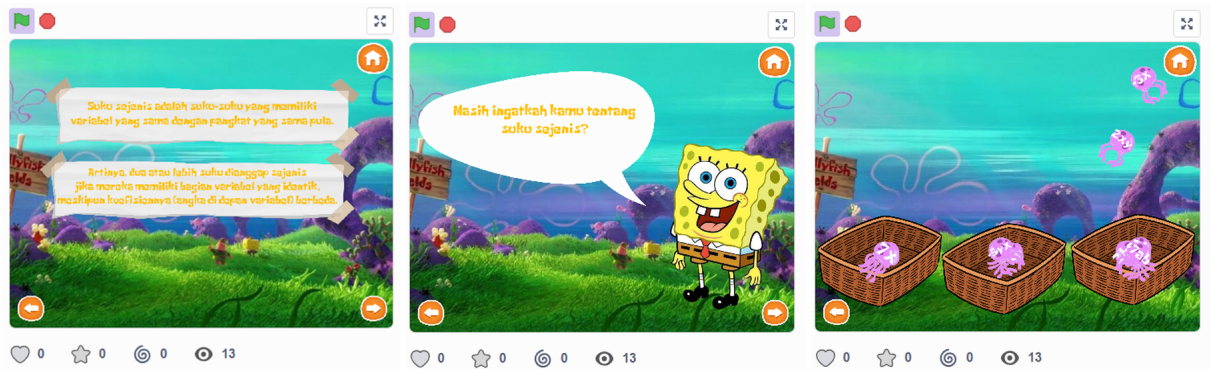

Figure 9. Like-Terms Learning Activity

Figure 9 presents an activity on like terms. Users place jellyfish into baskets according to the appropriate like-term groups. The game prevents incorrect placement and provides feedback before displaying a conceptual explanation. By combining classification, corrective feedback, and explanation, the activity links procedural action with the underlying concept of like terms.

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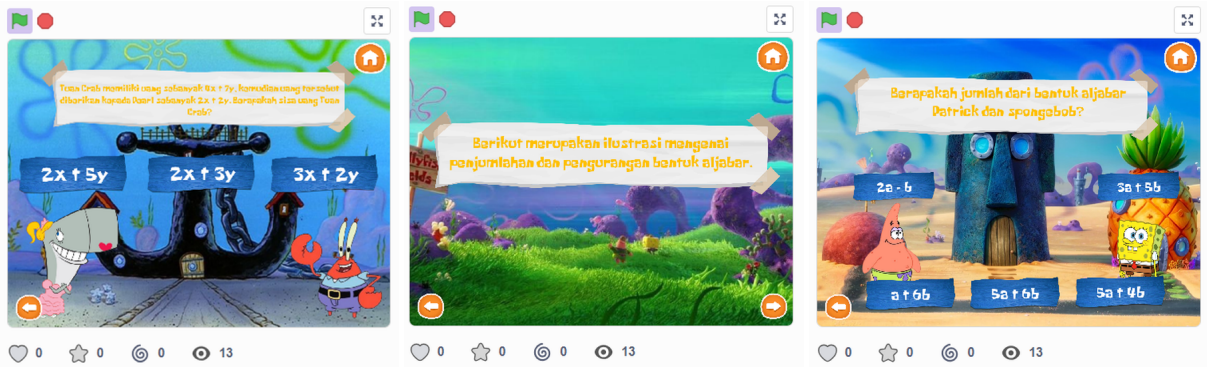

Figure 10. Addition and Subtraction Activity

Figure 10 presents addition and subtraction of algebraic expressions through conversations between the characters. Different character expressions and audio responses are displayed according to whether the selected answer is correct or incorrect. Presenting the operations through dialogue is intended to make symbolic procedures more accessible and connected to the game narrative.

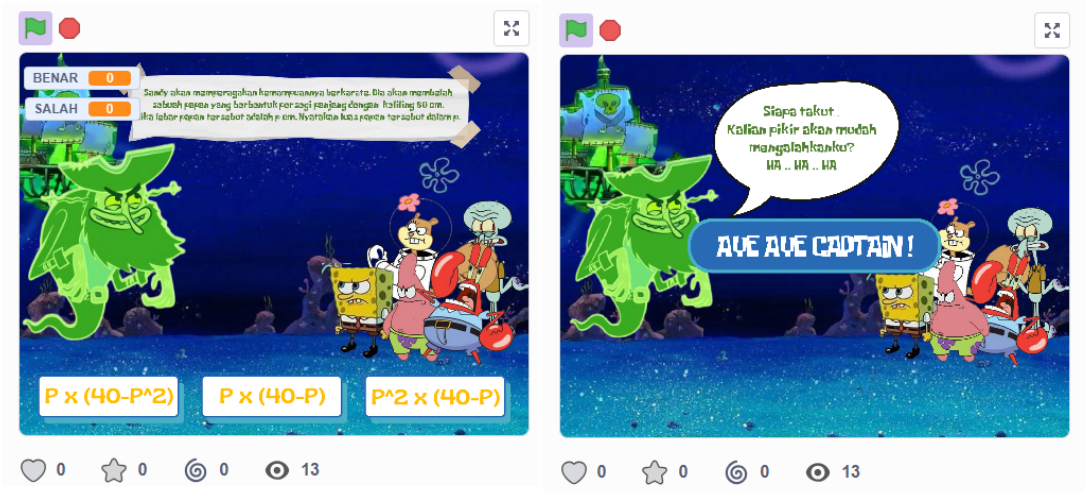

Figure 11. Game-Question and Result Displays

Figure 11 displays the contextual game. It contains five algebra story problems. The characters win if the user answers at least three questions correctly; otherwise, they lose. Visual effects and background audio support the game sequence. The scoring rule provides a clear completion target while the story problems require users to apply the concepts introduced in the preceding activities.

Testing

The prototype was tested repeatedly during development to check the accuracy and functionality of each component. After the internal testing stage, the open-ended questionnaire was administered to 18 pre-service mathematics teachers. Table 3 summarizes the coded responses.

Table 3. Pre-Service Mathematics Teachers' Responses

No.	ID	Appearance	Programming	Material	Language	Interest	Usefulness
1	P1	+	+	+	+	+	+
2	P2	+	+	+	+	+	+
3	P3	−	+	+	+	+	+
4	P4	+	+	+	+	+	+
5	P5	+	+	+	+	+	+
6	P6	+	+	+	+	+	+
7	P7	+	+	+	+	+	+
8	P8	+	+	+	+	+	+
9	P9	+	+	+	+	+	+
10	P10	+	+	+	+	+	+
11	P11	+	+	+	+	+	+
12	P12	+	+	+	+	+	+
13	P13	+	+	+	+	+	+
14	P14	+	+	+	+	+	+
15	P15	+	+	+	+	+	+
16	P16	+	+	+	+	+	+
17	P17	+	+	+	+	+	+
18	P18	+	+	+	+	+	+
Total Positive		17	18	18	18	18	18
Percentage		94%	100%	100%	100%	100%	100%
Category		Very good	Very good	Very good	Very good	Very good	Very good

+ = positive response; − = negative response.

The mean positive response across the six indicators was 99%, which was categorized as very good. Participants generally described the game as interesting, enjoyable, easy to operate, conceptually appropriate, understandable, and useful for learning algebra. The appearance indicator obtained 94%, while each of the other five indicators obtained 100% positive responses.

The only negative code was provided by P3 for the appearance indicator. During the follow-up interview, P3 stated that the characters' shapes and movements were interesting but explained that some sprite sizes appeared disproportionate at a particular screen resolution. This clarification indicates that the negative response concerned responsive scaling rather than the overall visual concept. The feedback therefore identifies a technical improvement needed for compatibility across different screen sizes.

Participants also gave positive responses concerning usefulness, interest, material, and language. Representative responses included: "The game is very interactive and reduces the boredom typically associated with learning algebra; it makes abstract concepts feel tangible" and "The storyline using familiar characters makes the explanation

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of coefficients, variables, and constants clear and easy to follow." Another participant explained that the integration of the material and game activities could help students develop conceptual understanding.

These findings are consistent with previous reports that Scratch can support learning motivation and mathematical creative thinking (Nisa et al., 2022) (Nabilah et al., 2024). The results also support earlier studies showing that Scratch-based games can be developed successfully through structured multimedia-development procedures (Sudihartinih et al., 2021a). Nevertheless, the responses represent initial feasibility feedback from pre-service teachers rather than evidence of effectiveness among the intended junior high school users.

Distribution

The completed prototype was stored on Google Drive and uploaded to the Scratch website. This stage made the product accessible for initial evaluation and future refinement. The distribution remained limited because the product used third-party character and audio assets and had not yet been tested directly in classroom instruction.

CONCLUSION AND RECOMMENDATIONS

The Scratch-based mathematics learning media entitled SpongeBob Squad in Algebra Wonderland was successfully developed through the six MDLC stages: concept, design, material collecting, assembly, testing, and distribution. The prototype integrates introductory algebra, algebraic elements, like terms, algebraic operations, and contextual problems within an interactive game. Initial users gave an average positive response of 99%, categorized as very good. The appearance indicator received 94%, while programming, material, language, interest, and usefulness each received 100% positive responses.

These results indicate that the prototype received very favorable evaluations from pre-service mathematics teachers. However, the study examined initial user responses rather than learning effectiveness, and the intended junior high school users were not involved. Future studies should therefore conduct trials with junior high school students and evaluate the media's effects on conceptual understanding, learning outcomes, motivation, and mathematics anxiety through classroom-based research.

Further development may extend the Scratch-based design to other mathematical topics, including geometry, social arithmetic, and linear equations. Future versions should also improve responsive scaling, graphics, animation, and navigation across different screen resolutions and align the learning activities more explicitly with the Merdeka Curriculum and the Pancasila Student Profile. Before wider distribution, copyrighted assets should be replaced with original or appropriately licensed materials, and the completed product should be registered for intellectual property protection.

Artificial Intelligence Statement: The authors declare that no generative artificial intelligence or AI-assisted technologies were used in conducting the research or preparing the submitted manuscript

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