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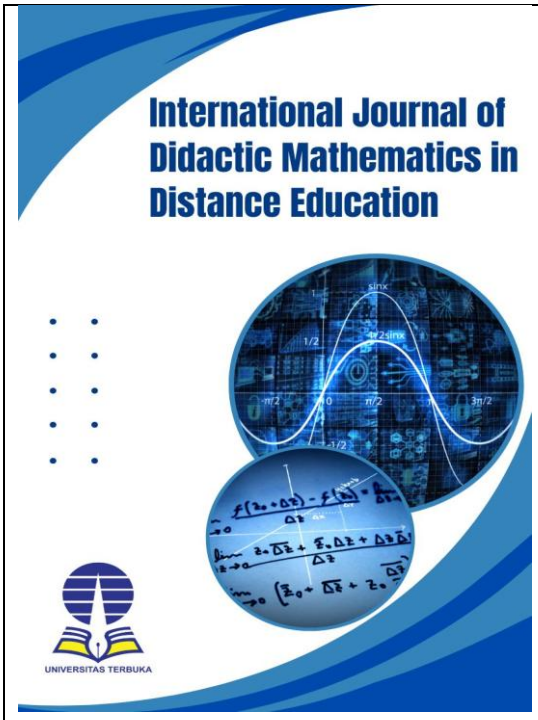

Development of digital learning media with articulate storylines 3 based on students' algebraic thinking skills

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Development of digital learning media with articulate storylines 3 based on students' algebraic thinking skills

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Abstract
This study aims to develop digital learning media designed to enhance students' algebraic thinking skills, addressing the urgent need for innovative instructional tools that foster higher-order mathematical reasoning. The research was motivated by the persistently low levels of algebraic thinking among students and the lack of engaging media that can support the development of these essential skills. Employing a research and development (R&D) approach, the study utilized the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—to guide the creation of an Android-based learning application focused on systems of linear equations in two variables. The study involved media and content expert validators who assessed the quality, relevance, and usability of the developed media. Data were collected through questionnaires and guided interviews, and analyzed using descriptive qualitative methods. The final product is a digital application that integrates algebraic thinking tasks and interactive content to support student engagement and conceptual understanding. Validation results from both media and content experts confirmed that the digital learning media is pedagogically sound and suitable for classroom use. Furthermore, student feedback indicated that the application is user-friendly, visually engaging, contextually relevant, and effective in helping them practice and strengthen their algebraic thinking abilities. This research contributes to the growing field of educational technology by offering a validated digital tool specifically designed to target algebraic reasoning. Future research should explore the broader implementation of this media across diverse learning contexts and its long-term impact on students' mathematical performance and motivation.

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1. Introduction

Mathematics is the science of logic concerning forms, structures, quantities, and other relational concepts that are numerous and divided into three fields: algebra, analysis, and geometry (Tall, 2008; Vergnaud, 2016). Algebra is one of the fundamental subjects essential for mastering other topics in

mathematics (Arcavi et al., 2016; Gambari et al., 2016). These topics include functions, linear, quadratic, inequalities, circles, trigonometric, and other materials that require algebraic operations (Kusumah & Mariani, 2024). Therefore, it can be said that mastering algebraic concepts is crucial in school mathematics and must be learned by students.

In mastering algebraic concepts, algebraic thinking skills are required. Algebraic thinking skills involve several activities in the thinking process, including generalization, abstraction, analytical thinking, dynamic thinking, modeling, and organization (Lew, 2004; Maudy et al., 2018). Kieran (2004) stated that generalization with patterns can form an understanding of functions, numbers, and their properties as a basis for solving problems using algebraic symbols and expressions. Algebraic thinking is one of the essential skills students must possess. This is because, through algebraic thinking, students can analyze, represent, and generalize symbols, patterns, and numbers presented in tables, words, pictures, diagrams, or mathematical expressions (Blanton & Kaput, 2011; Lingga et al., 2013; Tagle et al., 2016; Wilkie & Clarke, 2016).

Previous research shows that students' algebraic thinking skills are still low. This low level of algebraic thinking is evident from the relatively low average scores students achieved when working on algebraic thinking problems, with many students scoring below the minimum passing grade (Blanton et al., 2015; Pitta-Pantazi et al, 2020; Munthe & Hakim, 2022). This is due to students' difficulties in understanding and applying algebraic concepts, especially in solving problems related to algebraic forms in the topic of systems of linear equations in two variables (Pitta-Pantazi et al, 2020; Munthe & Hakim, 2022). The low level of algebraic thinking skills can be influenced by two factors: internal and external factors (Sidik et al, 2021). Internal factors relate to students' motivation to learn, while external factors include the teacher's role in choosing the method of delivering the material, which can affect students' mathematical abilities.

Thus, teachers must make efforts to help students understand algebraic concepts in the topic of systems of linear equations in two variables. One way to do this is by developing learning media based on algebraic thinking skills that can support the learning process. According to Sari et al. (2022), the use of learning media can influence students' learning outcomes. This is because learning media make the learning process more interesting, and effective, and can have a psychological impact on students. Learning media can be created by utilizing rapidly advancing information technology. Hasibuan et al. (2023) mentioned that the use of information technology-based media can increase students' interest in learning. Previous research that stated the relationship between learning using e-learning and algebraic thinking skills, one of which was Alzoebi (2023), who in her research stated that students who received flipped classroom learning gained a higher increase in students' algebraic thinking abilities compared to students who received conventional learning. Such media can make the learning process more engaging for students in the classroom. One tool that can support the creation of digital learning media is Articulate Storyline 3.

Articulate Storyline 3 is a mix-programming software that can create multimedia-based learning media, combining various elements such as text, images, graphics, sound, animation, video, interactions, and more, packaged into digital (computerized) files used to convey messages to the public (Handayani et al., 2020). According to Nissa (2021), Articulate Storyline is not yet widely used in research compared to other interactive multimedia, PowerPoint, and Adobe Flash. The published result of mathematics learning media from Articulate Storyline 3 comes in the form of an Android application, which is expected to assist teachers in delivering mathematics lessons to students and to attract students' interest and attention throughout the learning process (Wahyudi & Amry, 2022). Dwirahayu et al., (2019) stated that one way to hone students' algebraic thinking skills is through Schema-Based Instruction media Learning with the help of E-learning media which can attract students' interest and motivation to learn. Based on this, and several advantages of articulate storyline media, in this study the researcher suspects that using articulate storyline media can stimulate students' algebraic thinking abilities.

Based on the existing problems and potential, this research has developed a digital learning media using the Articulate Storyline application, specifically in the form of an Android-based learning media, to motivate students to learn mathematics and train their algebraic thinking skills. The objectives of the

research are (a) to produce digital learning media based on algebraic thinking skills; (b). To determine students' responses after using the digital learning media based on algebraic thinking skills.

2. Method

2.1. Research Design

The research method used is Research and Development (R&D). According to Borg & Gall (as cited in Sugiyono, 2022), educational research and development is a method used to develop and validate products. The development model used in this study is the ADDIE model, which stands for Analysis, Design, Development or Production, Implementation, and Evaluation, developed by Branch in 2009. The ADDIE model is used because, as stated by Pakabu et al. (2024), the development model requires testing and revisions multiple times, ensuring that even though the development procedures are simplified, they still include testing and revision processes. This ensures that the product developed meets the criteria of a good, empirically tested product, free of errors. Additionally, the ADDIE model is considered more rational and comprehensive. Therefore, the ADDIE model will be used, as it aligns with the research objective of developing digital learning media using Articulate Storyline 3 software.

The steps of the ADDIE model adapted in the context of Borg & Gall (2003) consist of five main stages. First, Analysis, which involves identifying learning problems or needs that must be addressed by collecting data from teachers, students, or subject matter experts. Additionally, an analysis of the competency standards that students must achieve is conducted, along with an examination of available resources such as technology or software. Second, Design, where learning solutions are designed based on the analysis results, including setting specific learning objectives and designing evaluation instruments. Third, Development, in which educational media products, such as software or digital teaching materials, are developed and tested by experts for feedback, followed by initial pilot testing with target users. Fourth, Implementation, where the product is applied in real-world settings, involving direct participation from students and teachers, as well as user training. Finally, Evaluation is conducted both formatively and summatively to assess the product's success, and based on the evaluation results, developers can make revisions to enhance the product's effectiveness.

2.2. Research Subjects

In this study, the research subjects are individuals or parties from whom the researcher collects data (Arikunto, 2014). The subjects in this research are as follows:

1) Media Expert Validator

The media expert validator in developing mathematics learning media is a doctoral lecturer in the field of learning technology who has expertise in creating learning media, whose qualifications are in accordance with this research. The steps taken by media expert validators include checking the consistency of visual design such as layout, use of color, images and multimedia elements. Validators ensure that the design is not only visually appealing but also supports the learning process effectively.

2) Material Expert Validator

The content expert validators in this research were three mathematics teachers who had master's degrees in mathematics education and a lecturer who was an expert in algebra. The task of the content expert validator is to check whether the learning content is in accordance with curriculum standards and learning objectives. Validators ensure that the media contains relevant material that can help students achieve the desired competencies.

3) Students

The student respondents in this research are 30 students who participated in the media trial and completed a questionnaire to provide feedback on the learning media that had been presented to them.

2.3. Data Analysis Technique

The data analysis technique used in this research is as follows:

1) Questionnaire Analysis

After all the data is successfully collected, the next step is to analyze the data. In this research, the technique used is descriptive qualitative analysis. The questionnaires used for media expert and material expert assessments are closed-ended questionnaires utilizing a semantic differential scale. The semantic

differential scale is used to measure the meaning of a word, and it was developed by Osgood (Sugiyono, 2018).

Table 1
Semantic Differential Scale

Very	Much	not...	1	2	3	4	Very ...

Respondents can provide answers on a scale ranging from positive to negative. Each response on the questionnaire will be assigned a score. A score of 4 indicates that the respondent's perception is very good regarding the statement, a score of 3 means their perception is good, a score of 2 indicates that their perception is not good, and a score of 1 indicates their perception is very poor. The answers include both positive statements (supporting the statement) and negative statements (not supporting the statement). This scoring system helps in determining how well the media or material is perceived by the respondents, providing insights into areas that may need improvement based on the responses.

2) Interview Results Analysis

The data obtained from student interviews regarding the need for learning media at the school were specifically collected during the needs analysis stage and will be used to design the learning media in the subsequent phase, ensuring that the media is effectively crafted. Additionally, the data gathered from interviews with teachers pertain to their assessment of the educational media that has been developed. This interview data helps identify the specific needs and preferences of the respondents, guiding the development of the media to ensure it meets educational requirements and aligns with the objectives of the learning process. This analysis will focus on extracting key themes and insights from the interviews to inform the design and content of the learning media.

3. Results and Discussion

3.1 Results

The development model used in this research is the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Below is a description of the research findings for each stage:

3.1.1 Analysis

In this stage, interviews were conducted with mathematics teachers and 10th-grade students. There are three types of analyses performed:

a. Needs Analysis

Data were collected through interviews with two teachers and six 10th-grade students. Based on the analysis, it was concluded that there is a need for digital learning media that students can access via their smartphones. Digital learning media can assist teachers in delivering material to students and help students easily understand the content. Additionally, it aims to optimize the use of technology so that students focus not only on the answers but also on understanding the material, to improve students' skills.

b. Determining Learning Objectives

This stage is aimed at defining the knowledge and skills that will be targeted as solutions to the identified problems. The learning objectives will influence the design and the product that the researcher will develop. In this phase, the researcher identifies the material, learning outcomes, and objectives based on the curriculum used in the school where the research is conducted

c. Student Characteristics Analysis

This phase seeks to assess students' abilities, experiences, and motivation for independent learning. The analysis revealed that students tend to be passive in discussions and rely on teacher explanations. Some indicators of algebraic thinking skills have not yet been met. Students need an approach that encourages active participation and builds confidence to ask questions. Additionally, strategies are required to increase students' interest in reading and focus on learning. The use of digital learning media by teachers is still rare, although students have used applications such as Checkmath, Brainly, and Quipper, primarily to find answers rather than to understand the material. Therefore, the researcher developed digital learning media using Articulate Storyline 3 software.

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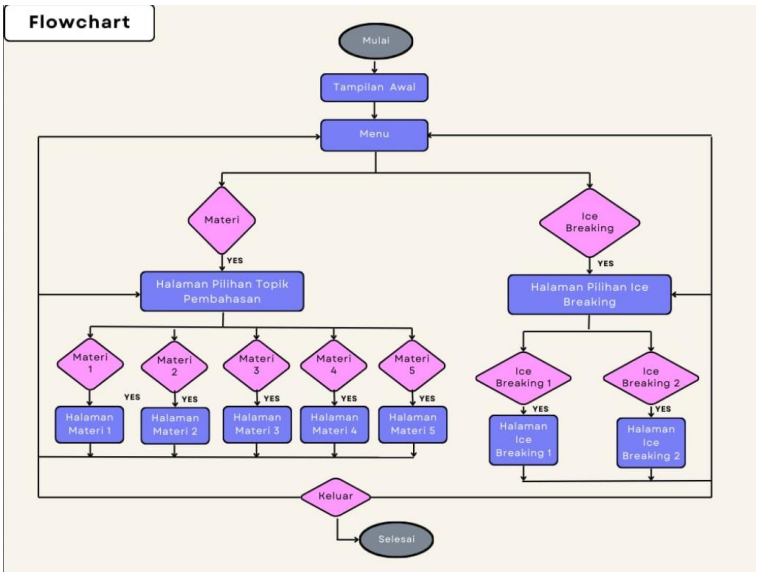
3.1.2 Design

a. Creating a Flowchart or Program Flow

This step involves creating a flowchart or program sequence from the beginning (entry), the content section, to the end (exit). The flowchart outlines the structure and flow of the digital learning media, supported by Articulate Storyline 3. Below is the flowchart of the digital learning media developed using Articulate Storyline 3. (You may want to insert the actual flowchart diagram here, showing the stages from user entry, navigation through content, interaction points, and exit paths). If you need further assistance with the structure of the flowchart or its components.

Figure 1

Digital learning media flowchart



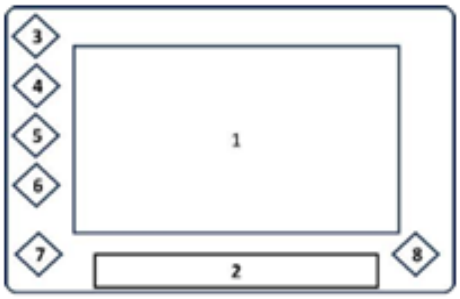
The flowchart in Figure 1 illustrates the process flow in the digital learning media, starting from the initial point (start) when students open the digital learning media. The user is then directed to the home page, which displays the main screen of the learning media. After that, there is a "play" button that leads to the login page, where users can input their name and school. Once both pieces of information are entered, clicking the "save and next" button will take the user to the menu page.

b. Creating a Storyboard

According to Oxford Cambridge and RSA, a storyboard is a series of diagrams showing the sequence of displays (Imbar et al., 2021). In this study, the storyboard consists of the layout, content, and presentation of the material. Once the storyboard is completed, it will be validated and submitted to a media expert validator to ensure that the content and presentation of the digital learning media align with the storyboard. Here is an example of a storyboard display in the creation of media using Articulate Storyline.

Figure 2

Material Page Display



The Material Page Display includes several key components. First, there is the material board, which contains navigation buttons for selecting different materials. Additionally, there is an image of a game

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menu. The navigation buttons consist of the following: the home button, which directs users to the main menu page; the sound on a button, which activates the background music; the sound off button, which turns off the background music; the video button, which leads to a video page relevant to the material being studied; the next button, which takes users to the next page; and the back button, which allows users to return to the previous page.

c. Designing Digital Learning Media

The design of the digital learning media is adjusted to the concept outlined in the previously created storyboard. In this design process, the necessary components for the media creation are developed. The key components of the media include: The design of the digital learning media interface is created using Canva and is aligned with the storyboard concept. The prepared materials are also tailored to fit within this design. The digital learning media interface design is as follows.

Figure 2

Material Page Display

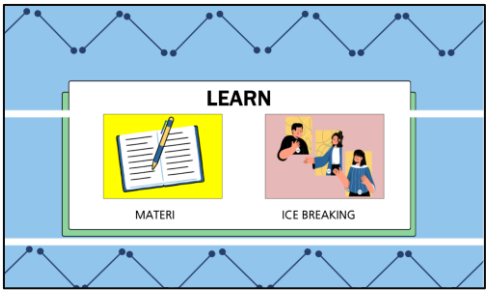


Figure 2 above shows the initial display before entering the material and ice breaking. When students select a section of material, the material to be studied related to SPLDV will appear as in the following image:

Figure 3

SPLDV material display

Based on Figure 3, the application of generalization in digital learning media assisted by an articulate storyline is contained in the material feature of the concept of a two-variable linear equation system in the picture, where the material and example questions are presented in detail. In this section, it is explained how a two-variable linear equation is formed from the given problem and the elements contained in the equation.

3.1.3 Development

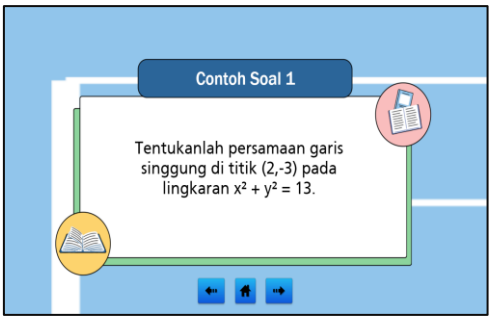
The development phase involves creating and testing the media. The media is built based on the development phase involves the creation and testing of the media. The media is built based on the flowchart and storyboard that have been previously created. This phase also focuses on producing usable media by making necessary revisions based on feedback from experts. At this stage, validation is conducted by media expert validators and material expert validators to ensure the quality and suitability of the media. Below is an explanation of the activities carried out during the development phase:

a. Media Creation

The digital learning media is created using Articulate Storyline 3, assisted by other applications and web tools such as Canva, PowerPoint, CapCut, and Website 2 apk Builder. The creation of this media is done by integrating the components that were developed in the previous phase. In line with Wardani et al. (2021), the creation phase is where all collected objects are transformed into an application. The media creation process involves two steps: creating media with Articulate Storyline 3 and converting HTML5 into an Android application. The steps for creating learning media in the form of an Android application are as follows: 1) Creating Media with Articulate Storyline 3, Open Articulate Storyline 3 that has been previously installed, then import the design layout made earlier in PowerPoint format into Articulate Storyline 3. Next, create quizzes and practice exercises using the "question bank" feature in Articulate Storyline 3 by inputting the questions that have been prepared beforehand into the feature. Then, create a result display using the "result" feature from the previous quiz creation, so that the quiz and exercise results can be viewed at the end of the session.

Figure 4

Question Image Display



2) Converting HTML5 to an Android application, After the media is created in HTML5 format, it is then converted into an Android application to make it accessible for students via mobile devices. These steps ensure that the digital learning media can be used easily on Android devices, enhancing its accessibility and usability for students.

b. Media validation

The media validation was carried out to evaluate the media developed in the previous stage. This process involved media experts assessing the quality of the design and subject matter experts reviewing the content's alignment, as well as the indicators of algebraic thinking skills with the material presented. Based on the evaluations from media expert validators, the following conclusions were drawn: From the assessments of three media expert validators on the design aspect, two validators rated the initial design of the digital learning media as attractive, while one validator rated it as very attractive. For the content display and navigation button design, two validators considered these features to be very attractive. All three validators agreed that the size of the buttons in the media was highly consistent. The image quality presented in the learning media was also rated positively, with two validators assessing the images as clear and one validator rating them as very clear. Regarding the audio aspect, the evaluation of the background sound indicated that the audio used was appropriate and the sound quality was clear.

Furthermore, based on the evaluation from subject matter expert validators, one validator stated that the media was fit for use without revision, while two validators suggested that it was suitable with minor revisions. The researcher noted several minor improvements that needed to be made to enhance the quality of the Sipermat digital learning media. After these revisions are made, the media will be submitted back to the subject matter experts for approval and subsequently tested with students.

3.1.4 Implementation

Once the media has been validated and deemed suitable, it is then implemented or tested with students to gauge their response to its use. In this implementation stage, the media was tested with 30 tenth-grade students. The researcher began by explaining how to use the media, starting with installation instructions and detailing each icon in the media.

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Next, the students were asked to engage with the learning material presented in both visual and audiovisual formats. They were also asked to complete practice questions and quizzes provided within the media. After using the media, students were asked to evaluate it based on three aspects: ease of use, attractiveness, and usefulness.The following are the results of the response questionnaire after the trial of the digital learning media.

Tabel 2

Student Response Results

Aspect	Indicator	Student frequency	
Ease	The media is easy to operate	25	5
	Button	24	6
	Clear instructions for use	25	5
Attractiveness	display quality	26	4
	Fictur	27	3
Usefulness	Presentation of Material is Relevant and Easy to Understand	27	3
	Training algebraic thinking skills	29	1
	Motivations	28	2
	Independent learning	28	2

Based on the table above, students' evaluations of the use of digital learning media indicate a positive response. There are also several suggestions and feedback from the students that will be further evaluated in the next stage. The following is student documentation on practicality test activities.

Figure 5

Practicality test activities

3.1.5 Evaluation

The evaluation phase is the final stage in the ADDIE development model, aimed at assessing the development of the learning media. This phase is conducted based on the results of media validation and students' feedback after the media trial. The evaluation results are used to provide feedback for the improvement of the media. Revisions are then made based on the evaluation results or unmet needs (Cahyadi, 2019). During the media validation process, the researcher revised the digital learning media based on suggestions from media and content expert validators, including the following:

1) The font size in the material section was too small;
2) The background image in the quiz section should be removed;
3) The sound in the learning video was drowned out by the background music;
4) A "try again" button should be added to the quiz result page when a low score is shown;
5) The images should be more varied;
6) The buttons in the menu should be modified to be more dynamic.

These revisions to the digital learning media were made to enhance and improve it, making it a ready-to-use product that can serve as a valuable tool in the learning process. In terms of evaluation, some

students could not install or use the digital learning media because their devices were iOS-based. Additionally, some students were less interested in reading the navigation button instructions due to the large number of button functions described. Another factor affecting the slow usage of the media was that it could only be accessed online. This happened because, before being converted into an Android app, the HTML5 output was first hosted online. However, overall, the students' responses were highly positive, particularly regarding the ease of use, attractiveness, and usefulness of digital learning media in the learning process. Here are some photos of teacher and student activities during the evaluation phase.

Figure 6

The teacher observes students in the media installation process

3.2 Discussion

In analyzing the limitations of this research, several important factors can be identified, highlighting both the challenges faced by the researcher and potential areas for further development. One key limitation is the technical constraint experienced in using the Website 2 APK Builder, which restricted the product to Android devices and required an online connection, excluding iOS users and limiting accessibility in areas with unstable internet. Additionally, the study did not include a formal measurement of students' progress or learning outcomes after using the media, representing a significant gap in assessing the effectiveness of the product. Another limitation lies in the lack of distribution through official platforms like the Google Play Store, which reduced the accessibility and adoption of the media among teachers and students, relying instead on less reliable methods like WhatsApp. Furthermore, the application's content cannot be independently updated by teachers, posing challenges for those wishing to adapt the material to specific classroom needs or curriculum changes. The practice questions within the application were created from a limited range of sources, potentially lacking in depth and variety to fully engage students' learning needs. Finally, the research was limited to a single school, which restricts the generalizability of the findings. To address these issues in future development, researchers should consider creating a cross-platform application, integrating performance tracking tools, making the media available on mainstream app stores, and allowing content updates by teachers. Expanding the research scope to multiple schools would provide more comprehensive data on the media's effectiveness across diverse learning environments. By addressing these weaknesses, future product iterations can be more effective, accessible, and impactful in enhancing students' algebraic thinking skills while offering greater flexibility to educators.

This study aligns with various previous studies that highlight challenges in the development and implementation of technology-based learning media, particularly in terms of accessibility, effectiveness, and flexibility in educational settings.

One of the main challenges in this study is the technical limitation caused by the use of Website 2 APK Builder, which results in the application being available only on Android devices and requiring a stable internet connection. This is consistent with the findings of Liu et al. (2021), who pointed out that platform limitations in educational applications often become a major barrier to the widespread adoption and implementation of technology in schools. Similarly, Adekotujo et al. (2020) highlighted that applications

available on only one operating system tend to be less inclusive, limiting learning opportunities for students who use iOS-based devices or other systems.

Additionally, this study does not include a formal assessment of students' progress or learning outcomes after using the media. This is similar to the findings of Clark & Mayer (2016), who emphasized that without data-driven evaluation, it is difficult to determine the effectiveness of technology-based learning. Likewise, Serdyukov (2017) stressed the importance of incorporating both quantitative and qualitative assessment methods in educational technology research to ensure that the developed innovations truly contribute to improving learning outcomes. Another limitation of this study is the absence of application distribution through official platforms such as Google Play Store. Almaiah & Al Mulhem (2019) also asserted that educational applications not available on official app stores are often less adopted by teachers and students, as they tend to prefer more accessible and trusted solutions.

Moreover, the content in the application cannot be independently updated by teachers, meaning they cannot adjust the learning materials to meet the specific needs of their classes. Mutisya & Makokha (2016) found that a lack of content flexibility is one of the main factors hindering the adoption of technology in education. Similarly, Wanner & Palmer (2015) demonstrated that learning applications that allow teachers to modify or update content are more effective in increasing student engagement and adapting to curriculum changes. Furthermore, the practice questions in this application are sourced from a limited database, posing a risk of insufficient variation to accommodate students with different levels of understanding. English & Gainsburg (2015) emphasized that diversity in practice question sources is crucial for enhancing students' critical thinking skills, particularly in subjects like mathematics that require multiple approaches to problem-solving.

To address these limitations, future research is recommended to: (a) Develop a cross-platform application (Android and iOS) to expand user reach. (b) Integrate student performance monitoring tools to objectively measure the effectiveness of the media. (c) Distribute the application through official app stores to enhance accessibility and adoption. (d) Enable content updates by teachers to improve instructional flexibility. (e) Incorporate a more diverse range of practice questions to better cater to students' varied learning needs. (f) Conduct research with a broader scope across multiple schools to increase validity and generalizability. By implementing these improvements, the next iteration of this product can become more effective, accessible, and impactful in enhancing students' algebraic thinking skills while still providing educators with the flexibility they need in their teaching processes.

Limitations

The study on the Development of Digital Learning Media with Articulate Storyline 3 Based on Students' Algebraic Thinking Skills has several limitations that should be acknowledged. One of the primary constraints is platform dependency, as the developed learning media is created using Articulate Storyline 3, which may not be fully compatible with all devices and operating systems, particularly iOS-based systems, potentially restricting accessibility for some students. Additionally, the media requires an internet connection for optimal functionality, posing challenges for students in areas with limited or unstable internet access. Another limitation lies in the scope of evaluation, as the study primarily focuses on students' algebraic thinking skills without extensively assessing other cognitive and affective aspects of learning. This could limit the overall understanding of the media's impact on students' mathematical competencies. Furthermore, the study does not include a longitudinal analysis, meaning the long-term effects of using the digital learning media on students' algebraic thinking skills remain unexplored. Future research should consider expanding the scope to evaluate broader mathematical skills, ensuring offline accessibility, and incorporating longitudinal studies to measure knowledge retention and transferability over time.

4. Conclusion

This study concludes that the developed Android-based digital learning media, created using Articulate Storyline 3, effectively supports the enhancement of students' algebraic thinking skills. The media was produced through a systematic process involving analysis, design, development, implementation, and evaluation. Expert validation confirmed the media's appropriateness for student use,

and necessary revisions were successfully incorporated prior to classroom implementation. The findings indicate that students responded positively to the digital media, citing its user-friendly interface, visually engaging design, and clarity of content. Moreover, the application facilitated meaningful practice, helping students develop essential algebraic reasoning skills.

This research addresses the growing need for accessible, technology-integrated resources in mathematics education, particularly those aligned with higher-order thinking competencies. As a contribution, the study provides a validated digital learning tool that can be adapted for use in various educational settings to foster students' conceptual understanding of algebra. Future research should explore the long-term effects of digital learning media on students' problem-solving performance and conceptual retention in algebra. Additionally, expanding the scope to include diverse mathematical domains and varied learner populations could offer deeper insights into the scalability and effectiveness of interactive digital tools in mathematics education.

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Author Contribution
Author 1: Conceptualization, Writing - Original Draft;
Author 2: Writing-Review & Editing, Formal analysis
Author 3: Validation and Investigation
Author 4. Writing - Review & Editing
Author 5. Writing - Methodology; and Visualization
Author 6. Writing - Review & Editing

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Conflict of Interest
The authors declare no conflict of interest.

5. References

Adekotujo, A., Odumabo, A., Adedokun, A., & Aiyeniko, O. (2020). A comparative study of operating systems: case of Windows, Unix, Linux, Mac, Android and IOS. *International Journal of Computer Applications, 176*(39), 16-23. https://doi.org/10.5120/ijca2020920494

Almaiah, M. A., & Al Mulhem, A. (2019). Analysis of the essential factors affecting of intention to use of mobile learning applications: A comparison between universities adopters and non-adopters. *Education and Information Technologies, 24*(2), 1433-1468. https://doi.org/10.1007/s10639-018-9840-1

Alzoebi, A. M., Ghunaimat, M. A., & Alawneh, E. A. (2023). The Effects of Flipped Classroom Strategy Based on" Addie Model" for Algebraic Skill Development. *Anatolian Journal of Education, 8*(1), 141-158. https://doi.org/10.29333/aje.2023.8110a

Arcavi, A., Drijvers, P., & Stacey, K. (2016). *The learning and teaching of algebra: Ideas, insights and activities*. Routledge.

Arikunto, S. (2014). Prosedur Penelitian Suatu Pendekatan Praktis. Jakarta : Rineka Cipta

Blanton, M. L., & Kaput, J. J. (2011). Functional thinking as a route into algebra in the elementary grades. In *Early algebraization: A global dialogue from multiple perspectives* (pp. 5-23). Berlin, Heidelberg: Springer Berlin Heidelberg.

Blanton, M., Stephens, A., Knuth, E., Gardiner, A. M., Isler, I., & Kim, J. S. (2015). The development of children's algebraic thinking: The impact of a comprehensive early algebra intervention in third grade. *Journal for research in Mathematics Education*, *46*(1), 39-87. https://doi.org/10.5951/jresematheduc.46.1.0039

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.

Borg, W.R & Gall, M.D. (2003). Educational Research: An Introduction 4 th Edition. London: Longman Inc.

Cahyadi, R. A. H. (2019). Development of teaching materials based on the ADDIE model. *Halaqa: Islamic Education Journal, 3*(1), 35–42. https://doi.org/10.21070/halaqa.v3i1.2124

Clark, R. C., & Mayer, R. E. (2001). Designing for E-Learning. In *Trends and Issues in Instructional Design and Technology* (pp. 524-540). Routledge.

Dwirahayu, G., Halpiani, M., & Kustiawati, D. (2019). Peningkatan kemampuan berpikir aljabar melalui pembelajaran Schema-Based Instruction dengan strategi FOPS. *FIBONACCI: Jurnal Pendidikan Matematika dan Matematika, 5*(2), 105-116. https://jurnal.umj.ac.id/index.php/fbc/article/view/3634/0

English, L. D., & Gainsburg, J. (2015). Problem solving in a 21st-century mathematics curriculum. In *Handbook of international research in mathematics education* (pp. 313-335). Routledge.

Gambari, A. I., Shittu, A. T., & Taiwo, O. A. (2016). Enhancing students' understanding of algebra concepts through cooperative computer instruction. *Pedagogical Research*, *1*(2), 55-65. https://doi.org/10.20897/lectito.201655

Handayani, N. P. Y., Pujawan, I. G. N., & Sudiarta, I. G. P. (2020). Development of interactive social arithmetic learning media based on Articulate Storyline 3 with a scientific approach for class VII junior high school students, *Jurnal Pendidikan dan Pembelajaran Matematika Indonesia, 9(1), 38–44. https://ejournal2.undiksha.ac.id/index.php/JPM/article/view/1513*

Hasibuan, H. Y., Oktiarina, V., Rezaini, M. S. H., Nulhakim, L., & Ruhiat, Y. (2023). Needs analysis for developing virtual field trips-based learning media in elementary school science learning. *Jurnal Penelitian Pendidikan IPA, 9*(8), 5834-5844. https://doi.org/10.29303/jppipa.v9i8.4261

Imbar, K., Ariani, D., Widyaningrum, R., & Syahyani, R. (2021). Various storyboards for learning media production. *Jurnal Inovatif Pembelajaran, 4*(1), 108–120. https://doi.org/10.21009/JPI.041.14

Kieran, C. (2004). Algebraic thinking in the early grades: What is it? *Mathematics Educator, 8*(1), 139–151.

Kusuma, A. P., & Mariani, S. (2024). Algebraic thinking profile of pre-service teachers in solving mathematical problems in relation to their self-efficacy. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(11), em2532. https://doi.org/10.29333/ejmste/15580

Lew, H.-C. (2004). Developing algebraic thinking in early grades: Case study of Korean elementary school mathematics 1. *Mathematics Educator, 8*(1), 88–106

Liu, C., Bano, M., Zowghi, D., & Kearney, M. (2021). Analysing user reviews of inquiry-based learning apps in science education. *Computers & Education*, *164*, 104119. https://doi.org/10.1016/j.compedu.2020.104119

Lingga, A., & Sari, W. (2013). The influence of algebraic thinking abilities on mathematical problem solving abilities (Case study in class VIII of SMP Negeri 1 Kaliwedi, Cirebon Regency). *Eduma: Mathematics Education Learning and Teaching, 2*(2). https://doi.org/10.24235/eduma.v2i2.45

Maudy, S. Y., Didi, S., & Endang, M. (2018). Student'algebraic thinking level. *International Journal of Information and Education Technology, 8*(9), 672-676. https://doi.org/10.18178/ijiet.2018.8.9.1120

Mutisya, D. N., & Makokha, G. L. (2016). Challenges affecting adoption of e-learning in public universities in Kenya. *E-learning and Digital Media*, *13*(3-4), 140-157. https://doi.org/10.1177/2042753016672902

Munthe, R. T. I., & Hakim, D. L. (2022). Analysis of algebraic thinking abilities of junior high school students in solving systems of two-variable linear equations problems. *Prisma, 11*(2), 371–383. https://doi.org/10.35194/jp.v11i2.2388

Nissa, A. D. A., Toyib, M., Sutarni, S., Akip, E., Kadir, S., & Solikin, A. (2021). Development of learning media using android-based articulate storyline software for teaching algebra in junior high school. In *Journal of Physics: Conference Series* (Vol. 1720, No. 1, p. 012011). IOP Publishing.

Pakabu, K. T. S., Sudirman, S., & Kandaga, T. (2024). Culturally contextualized E-Module based on Papua: why teachers and students need it for teaching linear programming material?. *EduMatSains: Jurnal Pendidikan, Matematika dan Sains*, *9*(1), 258-275. https://doi.org/10.33541/edumatsains.v9i1.5984

Pitta-Pantazi, D., Chimoni, M., & Christou, C. (2020). Different types of algebraic thinking: an empirical study focusing on middle school students. *International Journal of Science and Mathematics Education*, *18*, 965-984. https://doi.org/10.1007/s10763-019-10003-6

Priatna, N., & Sari, R. M. M. (2022). Analyzing students' mathematical spatial literacy using a project-based blended learning model. *Kreano: Jurnal Matematika Kreatif-Inovatif, 13*(1), 78–87 https://doi.org/10.15294/kreano.v13i1.34995

Sari, R. P. (2023). Application of problem-based learning with video assistance to the learning outcomes of science from students in class V elementary. *Journal of Digital Learning and Distance Education*, *1*(12), 387-394. https://doi.org/10.56778/jdlde.v1i12.107

Serdyukov, P. (2017). Innovation in education: what works, what doesn't, and what to do about it?. *Journal of research in innovative teaching & learning*, *10*(1), 4-33. https://doi.org/10.1108/JRIT-10-2016-0007

Sidik, G. S., Suryadi, D., & Turmudi, T. (2021). Learning obstacle on addition and subtraction of primary school students: Analysis of algebraic thinking. *Education Research International*, *2021*(1), 5935179. https://doi.org/10.1155/2021/5935179

Sugiyono. (2022). *Research and development*. Bandung: Alfabeta.

Tagle, J., Belecina, R. R., & Ocampo Jr, J. M. (2016). Developing algebraic thinking skills among grade three pupils through pictorial models. *EDUCARE*, *8*(2). 147-157. https://doi.org/10.2121/edu-ijes.v8i2.752

Tall, D. (2008). The transition to formal thinking in mathematics. *Mathematics Education Research Journal*, *20*(2), 5-24. https://doi.org/10.1007/BF03217474

Vergnaud, G. (2016). The nature of mathematical concepts. In *Learning and teaching mathematics* (pp. 5-28). Psychology Press.

Wahyudi, D.A & Amry, Z. (2022). Pengembangan media pembelajaran matematika articulate storyline 3 berbasis android. *Jurnal Fibonaci: Jurnal Pendidikan Matematika, 3*(1), 12–21. https://doi.org/10.24114/jfi.v3i1.35077

Wanner, T., & Palmer, E. (2015). Personalising learning: Exploring student and teacher perceptions about flexible learning and assessment in a flipped university course. *Computers & Education*, *88*, 354-369. https://doi.org/10.1016/j.compedu.2015.07.008

Wardani, R., Zakaria, M., Priyanto, P., Luthfi, M. I., Rochmah, I. N., Rahman, A. F., & Putra, M. T. M. (2021). An authentic learning approach to assist the computational thinking in mathematics Learning for elementary school. *Elinvo (Electronics, Informatics, and Vocational Education)*, *6*(2), 139-148. https://doi.org/10.21831/elinvo.v6i2.47251

Wilkie, K. J., & Clarke, D. M. (2016). Developing students' functional thinking in algebra through different visualisations of a growing pattern's structure. *Mathematics Education Research Journal*, *28*, 223-243. https://doi.org/10.1007/s13394-015-0146-y