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Differential learning assisted with SANTUY mobile application for improving students' mathematical understanding and ability

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Abstract

Equations are often used in mathematics and other subjects, which means that a media can teach students how to solve equations, particularly linear equations of two variables, or *Sistem Persamaan Linear Dua Variabel* (SPLDV) as it is called in Indonesian, is needed. However, most teachers are still focused on developing the learning process and teaching materials rather than developing an application technology-based learning media. As we know that technology-based learning is currently the focus of teaching and learning activities in the digital era, especially learning after the pandemic. This study aimed to develop an application that can be a reference for teaching media in learning activities to improve students' mathematical understanding and ability. The developed application is named, Integrated and Convenient Android-based Simulation or *Simulasi Android Terpadu dan Nyaman*, abbreviated as SANTUY. This development study with Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, explained in detail in the paper, took seventy-five subjects consisting of six expert validators, nine users, and sixty students. The expert validators comprised three media experts and three material experts. The evaluation stage involved students from two groups, each consisting of thirty students. The results showed that the average percentage of the feasibility of the SANTUY SPLDV solution simulation-assisted application with differential learning nuance was 79.62%, which means the application is adequate. The level of usefulness of the SANTUY SPLDV solution simulation-assisted application with differential learning nuance was 86.11%, which is categorized as "excellent". In addition, using the SANTUY SPLDV application had a direct positive influence on improving students' mathematical understanding and ability.

Keywords: Android, Differential Learning, Mathematical Understanding, SANTUY Application, SPLDV

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The current trend in the development of education in Indonesia is the implementation of *Kurikulum Merdeka* (Freedom Curriculum). The curriculum gives students the freedom to understand learning material according to their respective ability levels, and as a result, teachers must be ready to provide services as facilitators of knowledge to the students. In addition, the current learning space also shows that students' abilities and learning styles are more diverse and teachers no longer emphasize one learning for all, but must prioritize differential learning (Schiepe-Tiska, 2019; Subban, 2006).

Differential learning is a way of teaching each student differently and providing opportunities for students to choose in their process of absorbing educational content, which in this study is mainly emphasized in mathematics education content. Problems that arise in mathematics education include students having difficulty understanding and interpreting mathematical problems correctly (Dasaprawira et al., 2019; Hidayat et al., 2023; Pongsakdi et al., 2020; Widodo et al., 2020).

Current conditions show that students' mathematical understanding for learning linear equations with two variables tends to be poor (Ferdianto et al., 2019; Kaiser, 2020). This is indicated by the frequent mistakes found in the solution procedures applied by students (Al-Mutawah et al., 2019; Reit & Schäfer, 2020; Setambah et al., 2021; Verschaffel et al., 2020). In fact, mathematics learning is formulated horizontally and vertically (Ali et al., 2022; Hendriana et al., 2022; Hutajulu et al., 2022; Prahmana & D'Ambrosio, 2020; Pramuditya et al., 2022). Therefore, teachers and students need to comprehend the prerequisite material to understand the next material and understand the different ways in which mathematics might be presented to students.

The problem of poor mathematical understanding and ability can also be seen from Indonesia, which was ranked 46th out of 51 countries with a score of 397 in the Trends in International Mathematics and Science Study (TIMSS) 2015 Results in Mathematics, which assessed mathematics and science knowledge of students around the world with high-level cognitive questions that measure mathematical understanding and ability (Safari, 2021). In addition, the 2018 Program for International Student Assessment (PISA) result showed that Indonesia scored 379 in mathematics, which was a 7-point decrease from the previous score (Setiawan et al., 2021). This problem makes it urgent to conduct study and development that can produce a process of stimulating students' interest in mathematics by presenting the learning process more interestingly that has potential to lead to better engagement and student success. The expected learning process consists of learning simulations, solving mathematical modeling, and graphing linear equations with two variables.

Poor mathematical understanding is also exacerbated by the COVID-19 pandemic, which required the use technology for students to continue their education (Marbán et al., 2021). Educators and students had to understand how to learn with technology because of the implementation of online learning (Tang et al., 2021). However, many problems arise due to unpreparedness for learning mathematics online, which creates various adverse conditions for students such as lack of knowledge how to use technology, issues with the interaction between students and teachers, internet disturbances, material that is not explained optimally, and dearth of support resources from home, which is still very low (Pulungan et al., 2022). Therefore, information technology can be used as an alternative solution in supporting teaching and learning activities after the Covid pandemic, especially in mathematics teaching and learning process.

Information technology has now been utilized in many schools to implement Android-based interactive learning media using personal computers or smartphones. Although online learning using Android-based media is favored by students, there are also negative effects that arise, such as students becoming unfocused on learning because they are too busy accessing social media and playing games with their smartphones (Irfan & Wulandari, 2019).

Weak students' mathematical abilities through online technology learning, such as Android, were also experienced during the COVID-19 pandemic in Indonesia. Students need to become familiar with using Android as a learning medium (Hidayat et al., 2022). Initially, Android media was only used for virtual meeting applications such as Zoom Meetings and Google Classroom (Gunawan et al., 2021; Muqorobin & Rais, 2020). However, as time passed during the COVID-19 pandemic, many applications focused on helping prove mathematical material began to appear.

Android-based learning media utilizes the smartphone as a device in the learning process (Hidayat et al., 2022). Android is designed as an operating system that provides an open-source platform for developers to build mobile applications (Hakky et al., 2018; Hidayat et al., 2023; Irfan & Wulandari, 2019). Thus, Android-based learning media is a learning media that can be accessed anytime and anywhere using a smartphone, has a high level of usability, attractiveness, effectiveness, and efficiency, and can be used for self-learning. Even though there are still obstacles related to infrastructure, both devices' students still need to get and the internet network at school, however, these problems can be resolved with encouragement and assistance from each teacher, student, parent, and school.

The feasibility aspects of Android-based learning media consist of content or material aspects and media aspects (Hidayat et al., 2023; Irfan & Wulandari, 2019). Content or material aspects can be assessed in terms of suitability, quality of content and objectives, and instructional quality. Meanwhile, the media aspect can be assessed in terms of usability or navigation, aesthetics, integration, and technical quality. In addition, Sari and Wati (2020) suggested that good Android-based learning media contains aspects of practicality, visual appearance, language, and the effect on learning strategies. This is also in line with Hakky et al. (2018) who argued that Android-based learning media is said to be feasible if it meets (1) Aspect of material relevance; (2) Aspect of material organization; (3) Aspects of evaluation and practice problems; (4) Language aspect; (5) Aspect of the impact on learning strategies; and (6) Aspect of visual display. In addition, the assessment of the media considers: (1) Language aspect; (2) Aspect of the impact on learning strategies; (3) Software engineering aspect; and (4) Visual display aspect. Meanwhile, student responses are assessed using the impact on learning strategy and visual display aspects.

The similarity of the feasibility criteria for an Android-based learning media in this study use three criteria: material, media, and student response questionnaire. The material assessment criteria consist of six aspects, namely material relevance, material organization, evaluation and practice problem, language, impact on learning strategy, and visual display. Media assessment included assessment of language, impact on learning strategy, software engineering aspect, and visual display. Meanwhile, the aspects of student response questionnaire was based on practicality, visual display, language, and impact on learning strategies.

The authors were interested in creating and developing applications that can be a reference for teaching media in learning activities to improve students' mathematical understanding and ability. This study aimed to determine and examine the feasibility of Android-based mathematical solution simulation application with differential learning for linear equations with two variables in eighth grade, the usefulness of Android-based mathematical solution simulation application with differential learning on the material of linear equations of two variables in eighth grade, and the improvement of mathematical understanding and ability of students who used Android-based mathematical solution simulation application with differential learning.

METHODS

This development study used the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model and aimed to develop an application that can be a reference for teaching media in learning activities to improve students' mathematical understanding and ability. The stages of the ADDIE development model are presented in Figure 1.

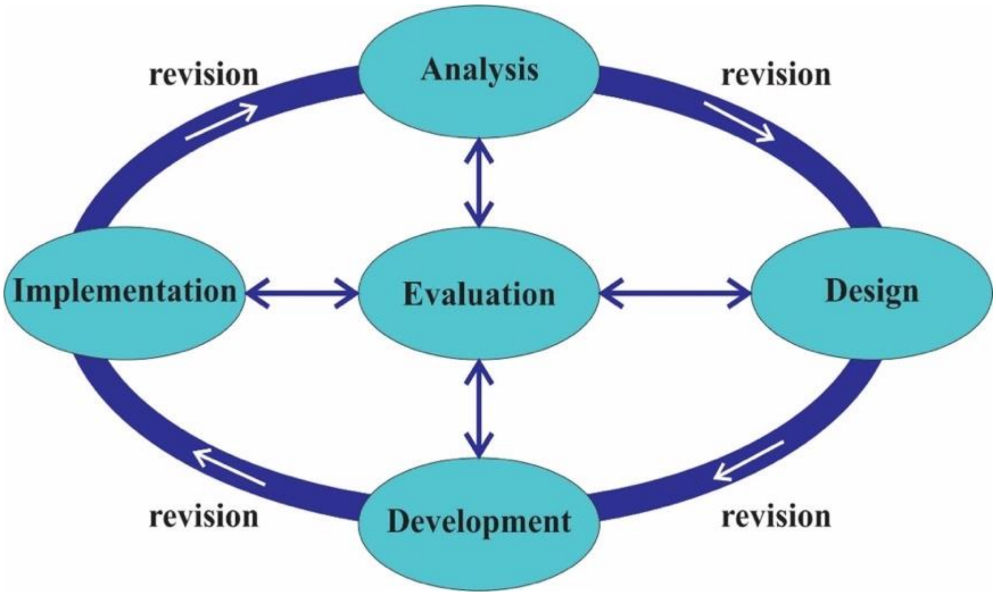


Figure 1. The ADDIE development model (Hidayat et al., 2023)

The flow of the development study conducted is as follows:

a. Analysis stage
The Analysis contains an analysis of learning needs and competencies that students must master. Details of activities during the analysis phase, in particular:
1. Analysis of user needs is a study conducted to determine what is needed to develop learning media.
2. Identifying needs (problems) seeks solutions that must be proposed in designing SANTUY learning media so that students master the required competencies.

b. Design stage
At this stage, scenarios are designed that will occur in learning. The results of scenario design are limited in a media that is expected to regulate student learning flow. After the scenario is formed, it is followed by designing the detailed flow of activities from each stage which in the end is made layout design.

c. Development stage
At this stage, media creation is carried out using Android Studio software. This software is intended for building Android-based applications with the Kotlin programming language as the primary language and extensible markup language (XML) as the programming language for the layout. Next, combine the flow and layout design into a single unit using the Kotlin programming language, Android Studio software, HTML, and CSS. Which, in the end, was validated by material experts and (Information Technology and Communication) ICT experts

d. Implementation stage, which comprised: (1) Hosting the application to Google Play Store; and (2) Conducting limited trial of the application to users through feasibility questionnaire.

e. Evaluation stage
At this stage, trials were carried out in experiments on applications on a broader scale to 60 students. The evaluation was carried out by an experiment intended to determine the quality of the finished product, namely the SANTUY learning media. This level of quality will be seen if the SANTUY

learning media can improve students' mathematical understanding and abilities. In this step, the researcher classifies data on students' mathematical understanding and abilities between those who study with SANTUY learning media and those who do not use SANTUY learning media.

All data obtained in this study were then analyzed and each stage of development was elaborated. The data processing procedures in this study are as follows.

a. To obtain valid results, validation was done by material experts and ICT experts. The material experts were three experts who met the requirements of teaching experience in linear equations with two variables. Meanwhile, the ICT experts were three experts who had experience in developing Android-based media. From the results of the validation of the material and ICT aspects, feedback related to mathematical content and related to the visual display of the application was obtained.
b. The average percentage of results of the assessment of the SANTUY SPLDV application was calculated using the following formula:

$$P = \frac{\sum S}{\sum S_i}\ x\ 100$$

Annotation:
P = Total questionnaire response percentage
$\sum S$ = Total score given by all validators
$\sum S_i$ = Total maximum score that can be given by all validators

c. The feasibility criteria for the application based on the assessment results are presented in Table 1.

Table 1. The feasibility criteria for the mobile application

Percentage	Criteria	Description
80% - 100%	Very Feasible	No Revision Required
60% - 79%	Feasible	No Revision Required
40% - 59%	Fair	Revision Required
0% - 39%	Not Feasible	Major Revision Required

RESULTS AND DISCUSSION

The result obtained from this development was learning media in the form of SANTUY mobile application for learning linear equations with two variables, or *Sistem Persamaan Linear Dua Variabel* (SPLDV) as it is called in Indonesian. The development was done through the stages in the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model.

Analysis Stage

At the analysis stage, the curriculum that was used as the basis for the development of media for learning linear equations with two variables was first determined. The curriculum used referred to the 2013 Curriculum (K-13). The next analysis was the analysis of activities that might occur in a learning activity (see Table 2).

Table 2. Predictions for learning activities

Activity	Activity Description	Possibilities of Student Thinking
Reading the list of key competencies and basic competencies to be learned	Students read each basic competency and key competency listed	- Students skim read. - Students read in detail. - Students can recall each basic competency and key competency.
Performing math addition operations	Students write the sum result of 4 + 6 =.....	Students remember and understand addition operations in mathematics.
Finding the sum of an addition operation	Students write the value of 4 + ... = 10	Students can find the value of .... so that 4 + ... = 10.
Observing the sum of addition operation	Students observe the left and right sides of the calculation 4+6 = 10	Students understand that both sides of an equation are equal.
Observing two addition operations	- Students observe the addition operations 4+6 = 10 and 4+x = 10 and see the difference between the two. - Students present their findings.	- Students can understand that 4+6 = 10 is true and 4+x=10 is not necessarily true. - 4+x=10 is true if x=6 - Students state there is no difference.
Determining variables and coefficients	- Students observe the statement 4+x = 10. - Students observe the variable x.	- Students state that the variable of the expression is x. - Students state that the coefficient of the variable x is 1.
Summarizing a mathematical statement	- Students re-observe the statement 4+x=10. - Students links their observations from the beginning of the lesson to the concluding session.	- Students understand that the equation is an equation with one variable. - Students state that an equation with one variable is an open statement. - Students state that the open statement has one variable. - Students define that a linear equation is the sum of numbers with variables that represent numbers.
Drawing the final conclusion	- Rewriting the equation 4+x =10 in x+4=10 - Converting each number to a letter; ax+b=c	- Students move the variable to the front of the equation. - Students mention that the coefficient of the variable x is 1. - Students define what a linear equation is.

The results of the analysis of the possibilities that might occur in learning activities (see Table 2) were then used as a reference for the concept of the application to be developed. The next analysis was a layout analysis to find an efficient and comfortable layout, especially on smartphones with a 4.5" screen. From the analysis, three layouts that would be used as the development design model were obtained and are presented in Figure 2.

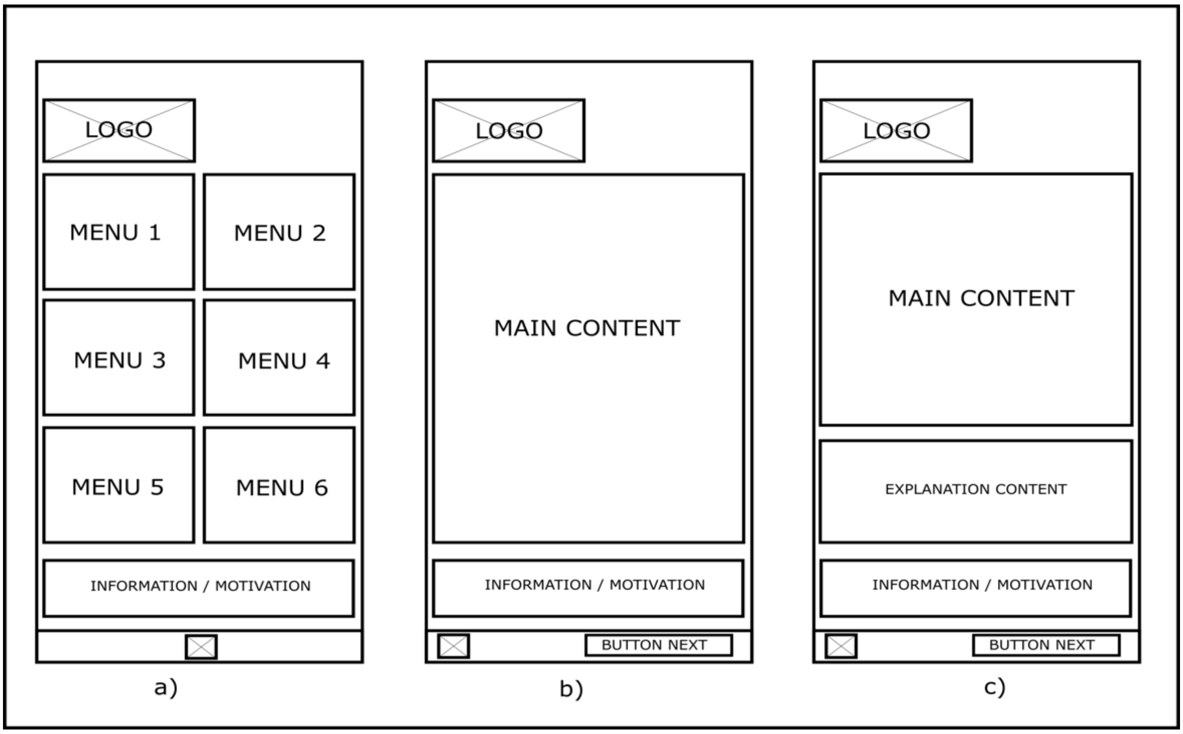


Figure 2. Media layout models

The three media layout models were classified according to their respective functions. Figure 2a is the main menu, Figure 2b is the general information material, and Figure 2c is the layout of material for which reinforcement of mathematical concepts is still needed.

Design Stage

At this stage, the scenario that would occur in the lesson was designed. The scenario was collated in a diagram as presented in Figure 3.

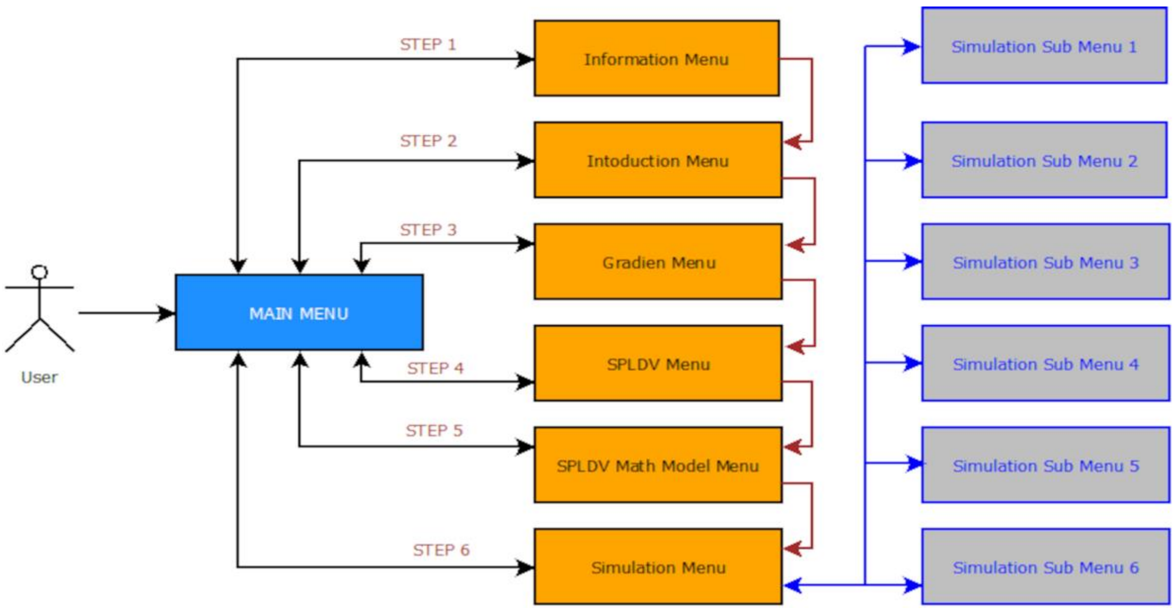
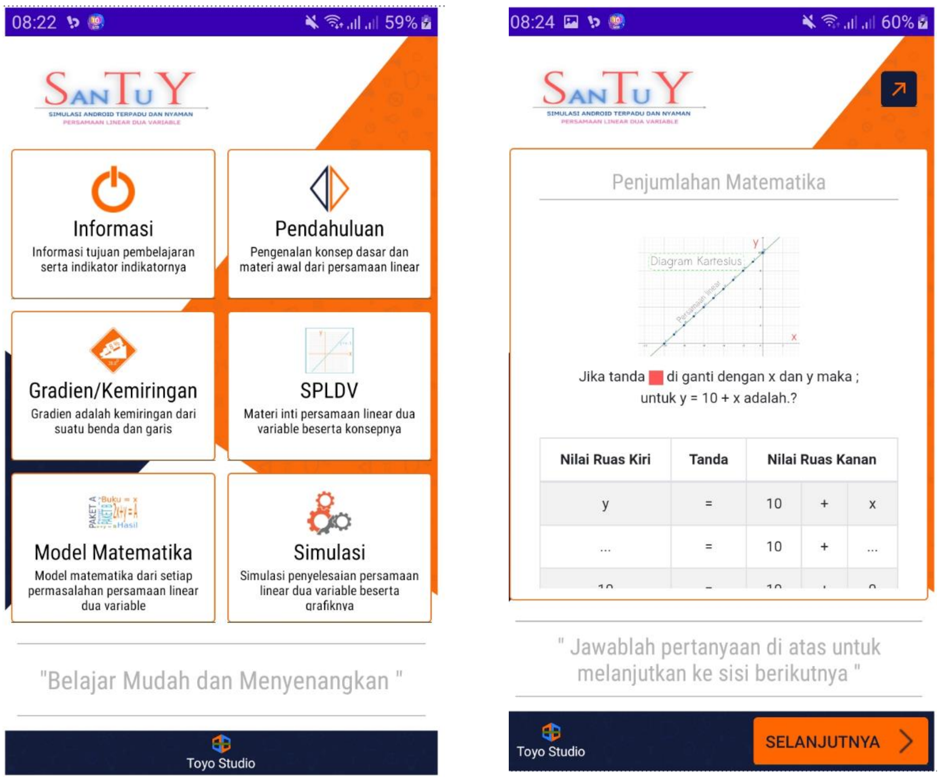


Figure 3. Media scenario concept

Then, level restrictions in the application were made based on the results of scenario design (see Figure 3) in order to organize the flow of how students learn. When the application is opened for the first time, only Stage 1 appears, while Stage 2 to Stage 6 is still gray, indicating that they are still locked and cannot be accessed.



First column translation:

Information Information on learning objectives and indicators	**Introduction** Introduction to basic concepts and initial material from linear equations
Gradient the slope of a line	**SPLDV** The core material of two-variable linear equations and their concepts
Mathematical Models Mathematical model of any problem of two variable linear equations	**Simulation** Simulation of solving two-variable linear equations along with their graphs
"Easy and Fun Learning"	

Second column translation:

Addition in Mathematics

If the ■ sign is replaced by X and Y, then for Y = 10 + x is?

Left Side Value	Notation	Right Side Value		
y	=	10	+	x
...	=	10	+	...

"Answer the questions above to proceed to the next side."

Next

Figure 4. Learning media layout design

After Stage 1 has been studied, the second stage is unlocked, then if Stage 2 has been completed, then

Stage 3 can be opened, and it continues like that until Stage 6. Meanwhile, the simulation sub-menu has no stages that must be passed because all material has been studied by the users.

After the scenario was created, the detailed flow of activities of each stage was designed. Then, a layout design was made (see Figure 4). The layout design that would be implemented in the media is expected to facilitate its use on Android-based media. The layout was designed using Inkscape software. This software was chosen because it is a free and open-source vector graphics software.

Development Stage

At this stage, the media was created using the Android Studio software. The software is used to build Android-based application with the Kotlin programming language as the main language and extensible markup language (XML) as the language for the layout. In the following figure, a layout created using XML is presented. Before starting to create a layout, the project was set up first using a smartphone with Android version 5.0 (Android Lollipop) and Software Development Kit (SDK) version 21. It was continued by creating layout using XML (see Figure 5).

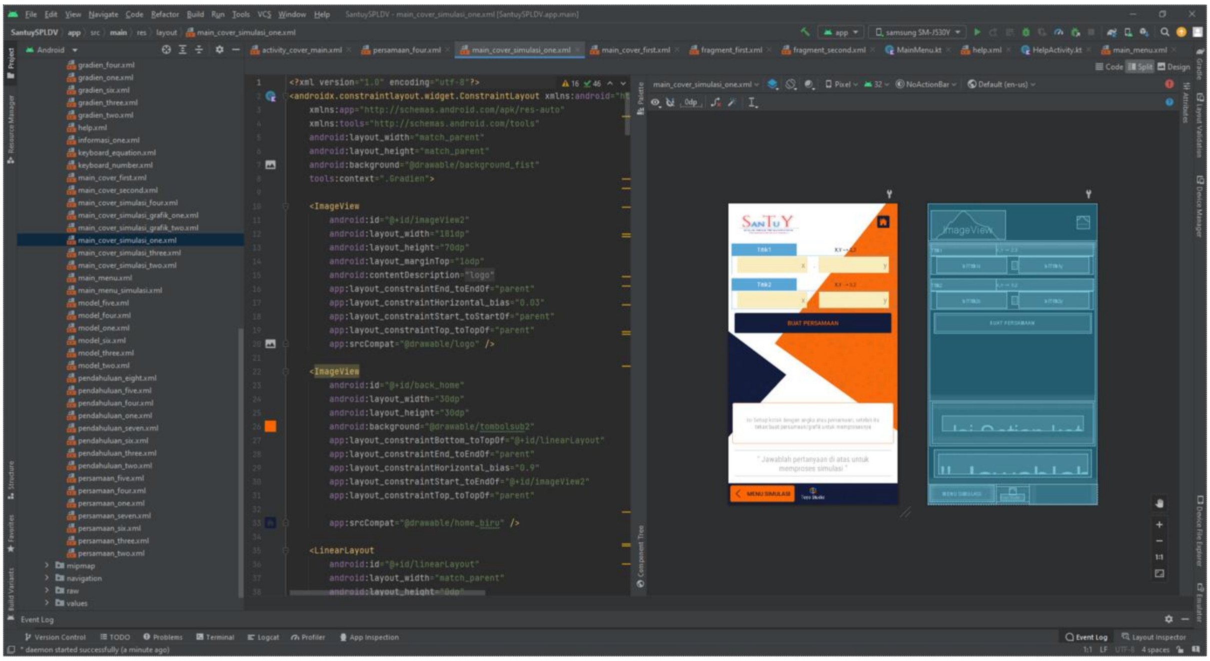


Figure 5. Layout design with form input

The next stage was to combine the flow and layout design into one unit using the Kotlin programming language, Android Studio software, and HTML and CSS. HTML and CSS are intended for display that still uses WebView. The combined result is presented in Figure 6.

Translated in English:

Equation 1 example: 2x + 3y = 6 Equation 2 example: 2x + 3y = 6 Drawing the equation Fill in each box with a number or equation	Equation 1 -> -1y = 2x + 5 Equation 2 -> 6y = 1x – 4 Simulation Menu Back

Figure 6. Equation picture processing form input

Furthermore, validation was conducted by material experts and ICT experts. The results of validation by material experts are presented in Table 3 and the results of validation by ICT experts are presented in Table 4.

Table 3. The results of validation by material experts

Assessment Aspect	Validation Percentage
Content feasibility	83.81
Understandability	83.33
Content suitability	84.76
Self-learning	83.33
Average	**83.81**

From the results of the assessment of the feasibility of the content of learning materials, the SANTUY SPLDV application obtained a score of 83.81% (see Table 3), meaning that the content of learning materials was classified as very feasible to use. Based on the aspects of understandability, suitability and self-learning, the content of learning materials was also classified as very feasible to use.

Table 4. The results of validation by ICT experts

Assessment Aspect	Validation Percentage
Concept and material	78.89
Usability	77.78
Visual display	70.00
Command button	75.00
Average	**75.42**

Table 4 shows that the average assessment result from media experts was 75.42%. It indicated that the SANTUY SPLDV application was classified in the feasible category. Based on the validation results from material and ICT experts, the SANTUY SPLDV application could be proceeded to media distribution.

Implementation Stage

At this stage, the application was ready for a limited trial. To facilitate the trial, the SANTUY SPLDV application was hosted in Google Play Store as a digital distribution service on Android-based devices (https://s.id/SANTUY-SPLDV-App). The media display on Google Play Store is presented in Figure 7.

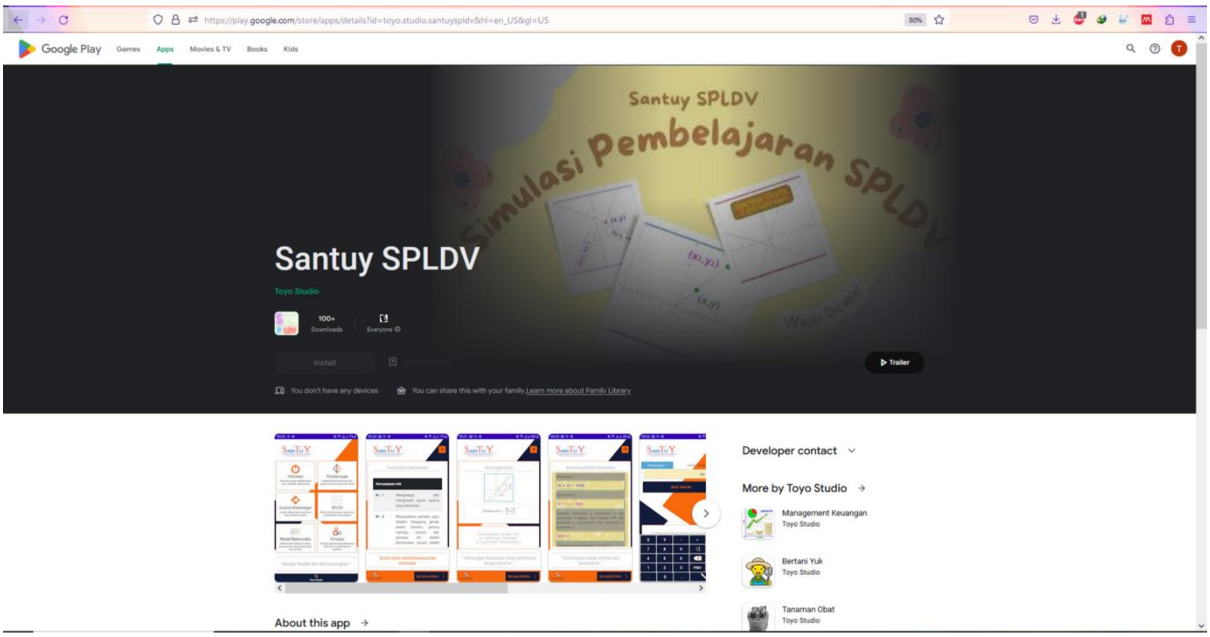


Figure 7. SANTUY SPLDV hosting on Google play store

The test was conducted to junior high school students and Islamic junior high school (MTs) students to determine the functionality aspects of the media, which are: a) Usefulness, b) Usability, c) Helpfulness, and d) Attractiveness of the application in learning activities. The number of students included in this limited trial was nine, comprising seven students of the Rajamandala Islamic Foundation Junior High School (MTs) and two students of Krida Utama Junior High School, Padalarang. Testing was done by trying all the features in the application, both the material feature and the problem-solving simulation feature, that have been made. Furthermore, the nine students gave their responses to the feasibility aspects of the SANTUY SPLDV application (see Table 5).

Table 5. Student response to the application feasibility

Category	Percentage
Usefulness	86.11
Usability	88.44
Helpfulness	91.67
Attractiveness	91.11
Average	**89.33**

Table 5 shows that the average percentage of feasibility was 89.33%, so the application media was categorized as feasible with no revision required. All students stated that there was no need for more elements to be added.

Evaluation Stage

The validated SANTUY SPLDV application was then applied in learning in two groups in order to see the effectiveness of the application on students' mathematical understanding and ability. The first group was an experimental group that received differential learning treatment with SANTUY SPLDV application, while the second group applied learning that did not utilize SANTUY SPLDV application.

The analysis of the improvement in mathematical understanding and ability in the group that received differential learning assisted by simulation solution (SANTUY SPLDV) and in the group that received conventional learning is presented in stages, starting from the result of the assumption or normality test to the result of the mean difference test. The result of the normality test of data on the improvement in students' mathematical understanding and ability (normalized gain) is presented in Table 6.

Table 6. The normality test of normalized gain (N-Gain)

Group	Statistic	df	Sig.
Experimental	0.933	30	0.058
Control	0.949	30	0.163

Table 6 exhibits that the data of both experimental and control groups were normally distributed. Thus, it was continued with the parametric test. Before conducting the mean difference test using the independent sample t-test, a test of homogeneity of variance was first conducted with the result presented in Table 7.

Table 7. Test of homogeneity of variance of N-Gain

	Levene Statistic	df1	df2	Sig.
Based on Mean	1.009	1	58	0.319

Table 7 displays that the variance of both experimental and control groups was homogeneous. Furthermore, the mean difference test was conducted using independent sample t-test (see Table 8) with the following statistical hypothesis formulation.

$H_0 : \mu_1 = \mu_2$
$H_1 : \mu_1 > \mu_2$

Testing criteria: If Sig. > 0.05, then H_0 is accepted.

Table 8. Independent sample T-Test

Competency	t	df	Sig.
Improvement in mathematical understanding	3.809	58	0.000

Table 8 shows that Sig. <0.05 (H_0 was rejected). Thus, it could be concluded that the improvement in mathematical understanding and ability among students who received differential learning assisted by SANTUY SPLDV application was better than that among those who did not use SANTUY SPLDV application.

The results of study on the development of learning media with the SANTUY application showed the effectiveness of the application on improving students' mathematical understanding and abilities. Based on the results of the interaction between learning resources stored in the application and students, learning with differential learning assisted by the SANTUY application could increase student interest in learning (Rohaeti et al., 2020; Sari & Wati, 2020). In addition, the SANTUY application is an application that is easily obtained and used by students so that it provides benefits to them in the process of solving problems through practice (Kurniansyah et al., 2022; Pertiwi et al., 2021).

The developed application summarizes the material of linear equations with two variables that can improve students' mathematical understanding and ability. The application has been developed in stages in order to produce learning media product that is suitable for use in the learning process. In the first stage in developing the application, needs analysis was conducted. The needs analysis contained an analysis of three kinds of needs, which were curriculum, material, and tasks, indicating that the development of the application is supported based on user needs, analysis of student learning styles, and curriculum analysis (Fahmi et al., 2019; Marbán & Mulenga, 2019; Rohaeti et al., 2019).

At the design stage, scenario drafting, and layout design were done. These two activities were also done in the study conducted by Hidayat et al. (2023) and the study revealed that the preparation of content outline and flowchart of an Android-based learning media by considering the characteristics of learners can provide an overview of the flow or course of learning media at each stage. In addition, through the outline and flowchart display, the application developer can be easier in developing the next stages (Herbst et al., 2014; Jones, 2008; Webel & Conner, 2017).

At the development stage, layout design and flow process were developed until the stage of validation by material experts and ICT experts. The validation process was done to provide positive feedback for improving the application developed (Fahmi et al., 2019; Nurwijayanti et al., 2019; Suarsana et al., 2018). In addition, the validation stage should also be based on an assessment of feasibility aspects such as language, impact on learning strategies, visuals, material relevance, organization of materials, and evaluation in the form of tests (Hidayat et al., 2022; Kurniansyah et al., 2022).

Based on the responses given by students as users at the implementation stage, this SANTUY SPLDV application has been declared feasible to use. Students who are the subject of learning need to understand the learning process using the application. The use of applications in the learning process is expected to improve students' understanding in learning mathematics and reduce the achievement gap between students with learning difficulties and students in general (Anwar et al., 2020; Domingo & Garganté, 2016; Zhang et al., 2015).

The evaluation stage in the form of an experiment of learning revealed that the mathematical understanding and ability of students who received differential learning assisted by SANTUY SPLDV application was better than that of students who learned without using SANTUY SPLDV application. One of the most dominant causes was the students' learning process which became more flexible. Students could learn anywhere and anytime. Students could also learn the material comprehensively and freely choose the material that they considered they did not understand through various material sections. This is in line with the characteristics of differential learning, which are being flexible and being able to provide learning assignments according to students' interests and learning readiness, but still referring to the learning objectives. Differential learning is also based on assessment and learning needs. Students determine their own way of learning with structured learning activities (Schiepe-Tiska, 2019; Subban, 2006). In line with that, Kurniansyah et al. (2022) argued that interesting and interactive learning media can provide motivation for students to learn.

CONCLUSION

The development process of the SANTUY SPLDV application has been subjected to the ADDIE development procedure, which consists of analysis, design, development, implementation, and evaluation. The developed application has been declared valid and practical and has been subjected to a trial to see its effectiveness. The general validation result obtained was 79.62%, with details of the validation result from material experts of 83.81% and the result of validation from ICT experts of 75.42%. Furthermore, the result of the practicality test on students as users was 89.33%, indicating that the SANTUY SPLDV application has a strong response so that the application is very practical to use.

The improvement in mathematical understanding and ability of students who obtained differential learning assisted by SANTUY SPLDV application was better than that of students whose learning did not use SANTUY SPLDV application. The improvement in mathematical understanding and ability of students who obtained differential learning assisted by SANTUY SPLDV application was in the "excellent" category (86.11%) and that of students who did not use SANTUY SPLDV application was in the "sufficient" category (78.24%).

The SANTUY application development study still needs to be improved in terms of materials and other mathematical competencies. Thus, future studies are expected to further examine the development of the SANTUY application in providing other mathematical materials and overcoming the difficulties faced by students in improving their higher-order thinking skills.

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Declarations

Author Contribution	:	EER: Conceptualization, methodology, writing the original draft, drafting revising and editing. BE: drafting-revising and editing, validation, and supervision. TW: Conceptualization, application design, data collection, formal analysis, and validation. RCIP: drafting-revising and editing, formal analysis, and supervision. WH: Conceptualization, data collection, formal analysis, and validation.
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Conflict of Interest	:	The authors declare no conflict of interest.

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