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DEVELOPMENT OF ONLINE LEARNING MEDIA USING GEOGEBRA AND LATEX ON DERIVATIVE MATERIAL

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ABSTRACT

Learning media in online learning is needed to understand mathematical concepts such as derivative material. Students need help connecting the derivative material with other materials, such as tangent equations. Technology-based learning media can be an alternative to help students improve their understanding of derivative concepts, one of which uses GeoGebra and LaTeX. The final product expected from this research is online learning media in the form of the GeoGebra web that students can access easily, which is in the valid category. This research is development research with a 4D development model. Due to the limitations of researchers, only three stages were carried out, namely, Define, Design, and Develop. The data collected in this study were obtained through validation sheets. Three experts carried out validation. The results of the validity test of the learning media developed belonged to the valid category with a score of 3,79. It can be concluded that online learning media is appropriate for use in classroom learning.

PENGEMBANGAN MEDIA PEMBELAJARAN DARING MENGGUNAKAN GEOGEBRA DAN LATEX PADA MATERI TURUNAN

Kata Kunci:

Pengembangan
Turunan
GeoGebra
LaTeX
Media pembelajaran daring

ABSTRAK

Media pembelajaran dalam pembelajaran online sangat dibutuhkan untuk memahami konsep matematika seperti pada materi turunan. Siswa mengalami kesulitan saat menghubungkan materi turunan tersebut dengan materi lain seperti persamaan garis singgung. Penggunaan media pembelajaran yang berbasis teknologi bisa menjadi alternatif untuk membantu siswa meningkatkan pemahaman terhadap konsep turunan, salah satunya menggunakan GeoGebra dan LaTeX. Produk akhir yang diharapkan dari penelitian ini yaitu media pembelajaran daring berupa web GeoGebra yang bisa diakses secara mudah oleh siswa, yang masuk pada kategori valid. Penelitian ini merupakan penelitian pengembangan dengan model pengembangan 4D. Karena keterbatasan peneliti sehingga hanya dilakukan 3 tahapan yaitu *Define*, *Design*, dan *Develop*. Data yang dikumpulkan dalam penelitian ini didapatkan melalui lembar validasi. Validasi dilakukan oleh tiga orang ahli. Hasil uji validitas terhadap media pembelajaran yang dikembangkan masuk ke dalam kategori valid dengan skor 3,79. Dapat disimpulkan bahwa media pembelajaran daring layak digunakan pada pembelajaran di kelas.

1. INTRODUCTION

Mathematics is one of the scientific disciplines that aid in advancing science and technology. However, mathematics is frequently regarded as a difficult and unpopular subject, resulting in students' mastery of mathematical concepts that could be more optimal, particularly on some topics that are considered difficult to imagine [1], [2]. Because the teaching process is successful if students understand the subject matter informed by the teacher, the conditions during online learning require teachers to expend more effort in the teaching and learning process so that the material can be conveyed and receive a positive response from students. [3]. However, in this modern era, many teachers still need to start using learning media in the teaching process because it requires careful preparation, and teachers only consider media as entertainment. In contrast, learning must be serious [4]. In other words, the current need in education is to develop and discover efficient teaching tools to assist educators and make certain lesson ideas easier for students to understand [5]. One of the solutions to the implementation of online learning is information technology [6]. Educators can use a variety of information media to conduct online learning [7].

Effective mathematics learning requires students to be stimulated to find concepts and to develop independence in finding mathematical concepts [8]. As a result, one of the most important aspects of learning mathematics is that students understand concepts well and correctly [9] because concept understanding serves as a foundation for solving various mathematical problems [10]. To solve mathematics problems, every student must have strong conceptual understanding skills [9]. According to Mashuri, concept understanding in mathematics is the fundamental thing that students must master before moving on to the next material because mathematics is one of the subjects where the material is interconnected, cannot be separated, and has a specific sequence [11].

In reality, many Indonesian students struggle with mathematical concepts [9]. The low conceptual understanding is reflected in the 2015 PISA results, where Indonesian students' mathematics learning achievement score was only 403 points, far below the international average of 493 and far below the scores obtained by other ASEAN countries such as Thailand (421), Vietnam (525), and Singapore (556). Indonesia finished 64th out of 72 participating countries that year [12]. Based on the international survey findings, it is clear that student's understanding of mathematics in Indonesia needs improvement. This is supported by Aziz and Sugiman's research, which found that students struggle to learn mathematics because they cannot remember and understand the concepts required to solve problems [13].

Calculus on derivative material is a topic in mathematics with many concepts. Memorization of formulas and computation mastery is not synonymous with correct knowledge of mathematical concepts and ideas in understanding derivative material [14]. One of the earliest descriptions of students' difficulties with derivatives came from Orton, who described significant misunderstandings of derivatives as rates of change and graphical representations of derivatives [15]. Ferrini-Mundy and Graham used interview techniques to learn about students' difficulties connecting symbolic representations of the derivative with their geometric form [15]. They discovered that students could calculate the derivative but could not relate the results to other materials, such as the equation of the tangent line, confirming Orton's findings. Sari and Wulandari's research yielded similar results on the derivative material of algebraic functions, indicating that learning outcomes remained low [16]. This should be used as reflection material for teachers to emphasize the importance of conceptual emphasis in calculus learning in high school [14].

Efforts can be made to assist students in online learning in improving their understanding of the concept of derivatives by visualizing how derivatives are represented in graphical form using online learning media. Gagne [11] defines learning media as "anything in the student's environment that can stimulate thinking." According to researchers' observations, while conducting Field Experience Programme activities at SMK Negeri 2 Banjarmasin, teachers are still fixated on video-based learning media obtained from YouTube, even though teachers should use various media to support learning in the academic field. Because using learning media that meets the needs of students can help students understand the material more easily, improving the quality of learning [17] and increasing the effectiveness of material delivery [18], this fact motivates researchers to create learning media that encourages students to interact with media or tools linked to teaching materials online for longer periods.

One software that can help students visualize graphs is GeoGebra. In learning mathematics, Geogebra is one of the interactive applications that can help make learning more interesting [19], [20]. GeoGebra is software that can be used to understand geometry, algebra, and calculus materials at various levels and can be accessed for free [1], [20]. GeoGebra is specifically designed for educational purposes. GeoGebra can help students develop experimentation and discovery learning on mathematical concepts [21]. Therefore, GeoGebra can be used to demonstrate and visualize geometry concepts and to make it easier for students to build geometry concepts on derivative material, such as the concept of common tangent and common tangent and the concept of derivative as a function limit.

One of the most difficult aspects of digital writing in mathematics is using many technical symbols and notations. In contrast, Microsoft Word or Open Office Suite applications impose strict limitations that can limit the mathematical notations or symbols used [22]. However, LaTeX allows anyone to produce more professional, attractive, and effective mathematical writing [22]. GeoGebra software itself supports the LaTeX writing language. One of the advantages of writing equations or mathematical language using LaTeX compared to Microsoft Word is writing equations or mathematical language that is more dynamic and neater [23]. Both software (GeoGebra and LaTeX) are free, this aims to minimize the use of pirated software that is often done by the general public.

Many development studies have used GeoGebra: GeoGebra to improve learning achievement [1], GeoGebra to improve understanding of concepts [2], and development of Geogebra-based learning tools [8], [9], [19]–[21], [24]–[31]. However, no one has integrated LaTeX with GeoGebra, so this research is expected to inspire other researchers to integrate LaTeX with GeoGebra. This study aims to create online learning media based on valid Derivative material using GeoGebra and LaTeX. Researchers believe that if GeoGebra is used as a learning media until the trial stage at school, it will be an effective and practical medium for students to understand the derivative concept material.

2. METHOD

This research is development research (Research and Development), with the model used is the 4D model introduced by Thiagarajan. The 4D development model consists of four stages consisting of the defining stage (define), the design stage (design), the development stage (develop), and the dissemination stage [32].

However, several stages are adjusted to the situation and conditions in the development research. The stages of development are only up to the development stage (develop), carried out an expert appraisal, not tested on students due to the COVID-19

pandemic and, not carried out the dissemination stage or dissemination to other schools due to limited time and resources. The complete development procedure carried out by researchers will be described based on Figure 1 below.

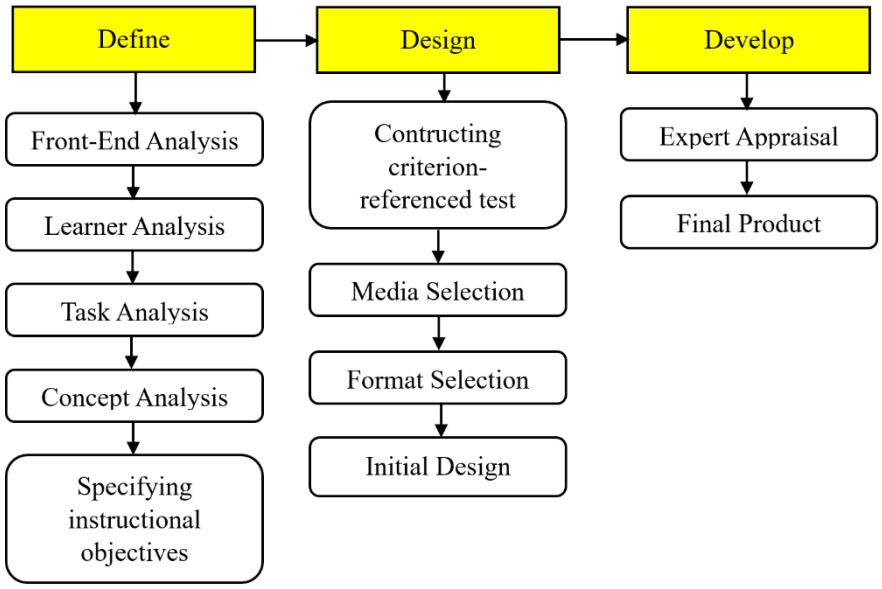


Figure 1. Development Flow with the Modified 4D Model

The instrument in this research is a validation sheet. This instrument is used to obtain information about the validity of learning media based on expert judgment. The information obtained through this instrument will later become a consideration for revising the learning media to be suitable for use. Three experts carried out validation to know the validity of the media that had been developed. The assessment on the validation sheet uses a scale of very less, less, enough, good, and very good. Then the validator is asked to provide a general assessment conclusion with the category worth using (LD), worth using with improvement (LDP), or not worth using (TLD).

The data used in the development of this media are qualitative in the form of criticisms and suggestions from validators on the media developed and quantitative data in the form of scores obtained from validation sheets filled out by validators. All these data are used to revise and assess the quality of the learning media developed to produce learning media that meet valid criteria.

Data analysis techniques in this development research were carried out with the following steps [33].

(1) Recapitulate the validity assessment data of learning media in a table that includes aspects (A_i), indicators (I_i), and values (V_i) for each validator.

(2) Calculating the average score of all validators for each aspect of the assessment. The formula used to find the average with the following formula [33].

$$I_i = \frac{\sum_{j=1}^{n} V_{ji}}{n} \qquad (1)$$

Description:

I_i = the average validation result

V_{ji} = the validator's score data on the i-th indicator

n = the number of validators

(3) Determine the average score for each aspect with the following formula [33].

$$A_i = \frac{\sum_{j=1}^{n} I_{ji}}{m} \qquad (2)$$

Description:

A_i = the average for the i-th aspect

I_{ji} = the average of the i-th aspect of the j-th indicator

m = the number of indicators in the i-th aspect

(4) Determine the value (V_a) or the total average value of all aspects using the following formula [33].

$$V_a = \frac{\sum_{i=1}^{n} A_i}{n} \qquad (3)$$

Description:

V_a = the average score for all aspects

I_{ji} = the average for the i-th aspect

n = the number of aspects

To determine the validity criteria based on the V_a value or the average value for all aspects, Table 1 is used based on Hobri [33] below.

Table 1. Criteria of Validity

Total Average for All Aspects	Criteria
$\mathbf{25\% \leq V_a < 50\%}$	Not valid
$\mathbf{50\% \leq V_a < 75\%}$	Less Valid
$\mathbf{75\% \leq V_a < 100\%}$	Valid
$\mathbf{V_a = 100\%}$	Highly valid

3. RESULTS AND DISCUSSION

The final product of this development research is online learning media using GeoGebra and LaTeX on Derivative material. This development research uses a modified 4D development model with the following stages.

3.1 Define

3.1.1 Front-End Analysis

At this stage, observations were made during the Field Experience Program (PPL) activities at SMK Negeri 2 Banjarmasin to discover the obstacles teachers and students experienced in the teaching and learning process. In mathematics subjects, SMK Negeri 2 Banjarmasin students use the 2017 Revised 2013 Curriculum Student Book.

Teachers still use media limited to video-based media sourced from YouTube, of which there are still few videos that can help students understand a concept intuitively, such as calculus. Although it has many advantages in its use, videos cannot be used as learning media for every meeting or face-to-face because it will present something monotonous and boring [9] and students cannot give input and then get feedback from the learning media, so they are limited to what is conveyed in the video. Based on these problems, it was decided to create a learning media on derivative concept material where students can provide input and get feedback, one of which is by using GeoGebra software.

3.1.2 Learner Analysis

Based on the results of observations during the implementation of PPL activities at SMK Negeri 2 Banjarmasin, it is found that students still cannot understand the material that requires an understanding of concepts, so when teaching the next material students

find it difficult because the previous concepts have not been understood properly. After all, concept understanding is fundamental to making students able to solve new forms of problems they will face by necessity in the future [34].

3.1.3 Task Analysis

The materials discussed in this learning media are (1) The concept of secant line and tangent line, (2) Derivative as a limit function, and (3) the Derivative of an algebraic function.

3.1.4 Concept Analysis

Based on the 2013 Curriculum for grade XI students, a chapter containing Calculus material is obtained, namely Chapter 7 Derivative. The main material discussed in Chapter 7, Derivative, is the concept of derivatives and derivatives of algebraic functions. Specific learning objectives are compiled based on the analysis of the previous four stages, Basic Competencies, and Competency Achievement Indicators in the syllabus.

3.2 Design

3.2.1 Constructing Criterion-Referenced Test

The test preparation refers to the competency criteria that must be achieved based on the specific learning objectives. Through the test questions, students can determine the equation of the tangent line at a point and the derivative of the algebraic function using the concept of limit and derivative rules appropriately.

3.2.2 Media Selection

The selection of GeoGebra media is based on the fact that GeoGebra can help students more easily understand calculus concepts [2] and increase student learning interest when used in the learning process [35]. GeoGebra is very suitable for drawing graphs of algebraic functions and can provide input to view function graphs according to the wishes of students [1]. This kind of thing cannot be obtained in learning media using other software.

3.3.3 Format Selection

The developed online learning media contains Home, Instructions, Syllabus, Materials, Exercises, and Compiler menus.

3.3.4 Initial Design

At this stage, the images used in the learning media begin to be created. Some images are taken from freepik.com and Microsoft PowerPoint and then edited using Adobe Illustrator. LaTeX is used and edited in writing the material using TeXstudio and Microsoft Word software with the same typeface, Latin Modern Roman. At this stage, the media design that has been made is called the first draft. The initial display of the learning media is presented in Figure 2 below.

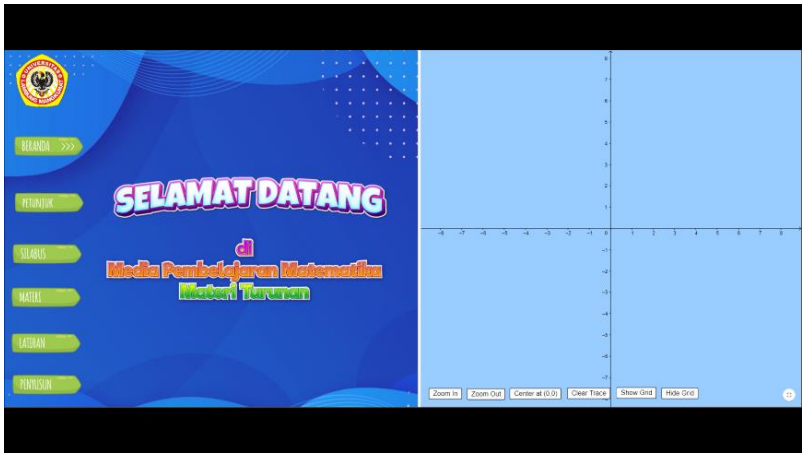


Figure 2. Initial Display of the Learning Media

On the Material and Exercise pages, several shapes edited from Microsoft PowerPoint were used to place the material and exercise questions. The Material page is shown in Figure 3, and the Exercise page is in Figure 4 below.

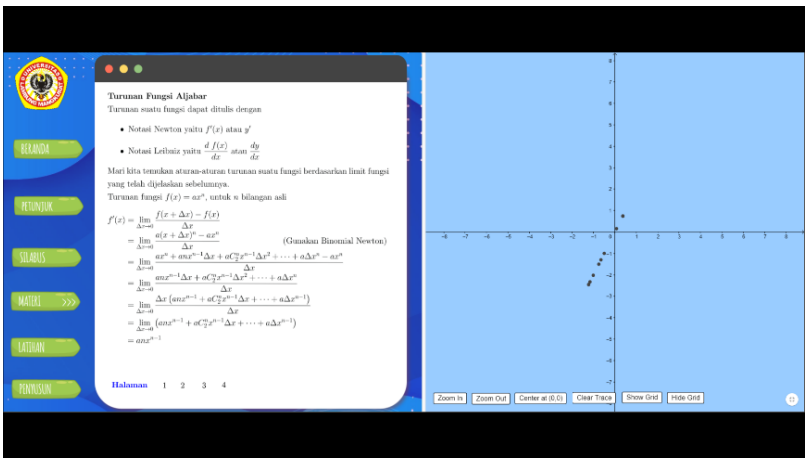


Figure 3. The Display of the Material Page

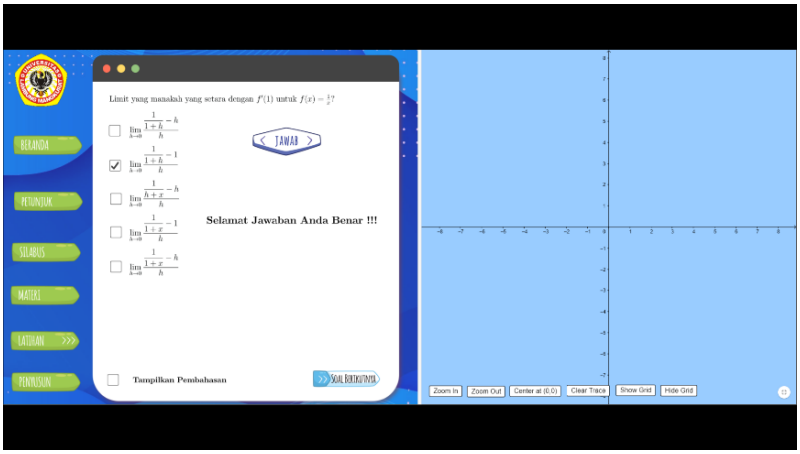


Figure 4. The Display of the Exercise Page

Then at this design stage, research instruments in validation sheets were also prepared.

3.3 Develop

In this development stage, revisions were made to the first draft media based on suggestions from the supervisor, and the second draft media was produced. The first draft media that has been made only contains general instructions and does not contain specific instructions on how to use the learning media, so those who use the media for the first time will feel confused. The addition of instructions is presented in Figure 5.

Figure 5. Addition of Instructions

The second draft media was submitted to three validators: two material experts from the Mathematics Education Study Program lecturer and one media expert from the Lambung Mangkurat University Educational Technology Study Program lecturer. Each validator was given learning materials and a validation sheet, which was filled out by checking the appropriate score. The validator provided an assessment score and several comments and improvement suggestions. The second draft media was then revised based on expert comments and suggestions. The following are some outcomes of revising the second draft media based on validators' comments and suggestions.

Color composition changes and background image redesign. Blue was the background color in the second draft media, and green was used for the buttons. The color was then aligned to green, and the background design was changed by adding geometric shapes such as cubes. The left view is before the revision. The right view is after the revision, and so on for the following images. Figure 6 depicts the color composition changes and redesign of the background image.

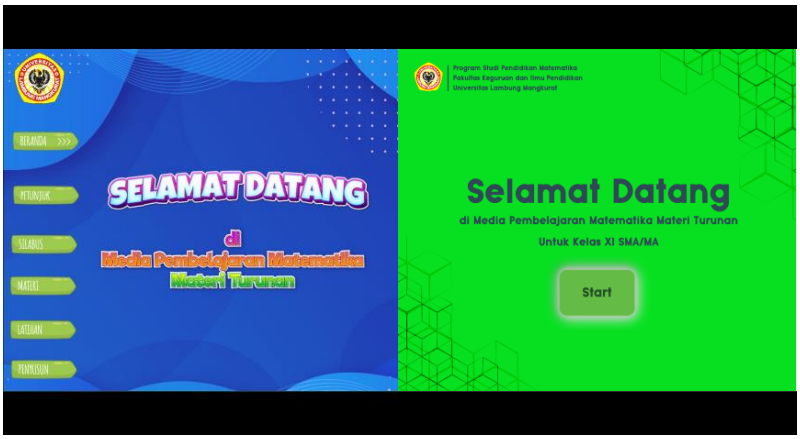
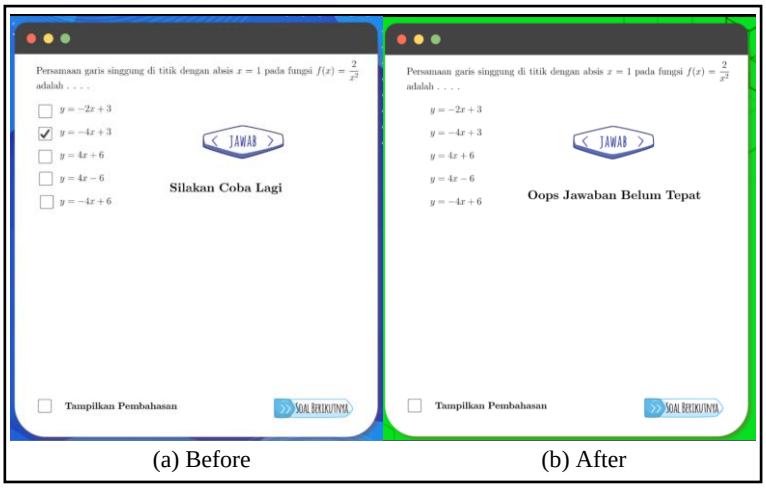


Figure 6. Color Composition and Background Image Changes

The exercises have been made more interactive. In the second draft, learners select the available answer options from the Exercise menu and press the answer button. The answer is then displayed as correct or incorrect. However, students can select the answer and press the answer button again to obtain the correct answer through trial and error. Based on this, it is designed so that the exercise question can only be answered once before moving on to the next, with no ability to change the answer. Figure 7 depicts enhancements to the exercise menu.



(a) Before (b) After

Figure 7. Changes to the Exercise menu

Addition of ski board illustrations to make it easier for students to imagine the position of the normal line. The added illustration is a moving animation. The skier in the display moves up and down, following the curve that is likened to an iceberg. The addition of illustrations is presented in Figure 8.

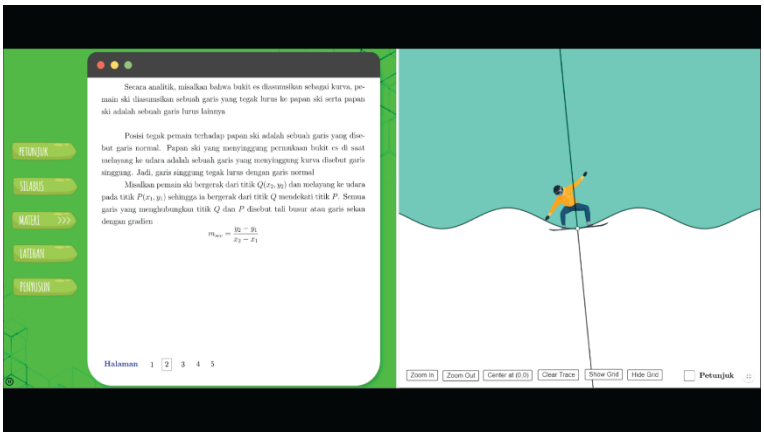


Figure 8. Addition of Skier Illustrations

There are 19 statements in the validation sheet for material experts in Table 2 and 17 statements in the validation sheet for media experts in Table 3. Sugiyono says validation is accomplished by having experienced experts evaluate new products to identify their strengths and weaknesses [36]. The material expert provided a score of 3.816 or 76,32%, and the media expert provided a score of 3.765 or 75,3%. Therefore, the average score of 3.79 or 75,8% was obtained (valid category). Based on the validity criteria [33], the developed online learning media has met the criteria. This is in line with the research conducted by several researchers [8], [24]–[26]. To summarize, GeoGebra

media on this derivative material met the valid criteria. Media that has gone through the validation and revision process can be accessed at https://www.geogebra.org/m/x4atf6yf.

Table 2. The Results of Validation on Material Aspects

Scoring Criteria	Validator			Mean
	1	2	3	
Accuracy of material with learning objectives	4	4	-	4
Accuracy of material with Basic Competencies (KD)	4	4	-	4
Completeness of the material presented	4	4	-	4
Depth of material presented	3	4	-	3,5
Providing examples to clarify the material	4	4	-	4
The use of media can attract students' interest and attention	3	4	-	3,5
The concepts presented are correct	4	4	-	4
The delivery of the material is sequential/coherent	4	4	-	4
Accuracy with student growth	4	4	-	4
Can make it easier to understand the lesson	3	4	-	3,5
It can be used for self-study	4	3	-	3,5
Can increase motivation/passion for learning	4	3	-	3,5
Can increase student curiosity	3	3	-	3
Media can be used in various situations	4	3	-	3,5
The language used is easy to understand	4	4	-	4
The sentences used are interactive	4	4	-	4
The questions presented in the evaluation are sufficient	4	4	-	4
The questions presented are relevant to the material	5	4	-	4,5
The media used can provide learning experiences for students	4	4	-	4
Mean				3,816

Table 3. The Results of Validation on Media Aspects

Scoring Criteria	Validator			Mean
	1	2	3	
Navigation on the main menu is easy to use	-	-	4	4
Navigation on the material menu is easy to use	-	-	4	4
Navigation on the material menu is easy to use	-	-	4	4
Navigation on the syllabus menu is easy to use	-	-	5	5
Navigation on the instructions menu is easy to use	-	-	4	4
Overall, navigation is easy to use	-	-	4	4
The language used is communicative	-	-	4	4
The language used is easy to understand	-	-	4	4
The size, color, and shape of the writing are correct	-	-	3	3
The images presented are sharp/not broken	-	-	3	3
Harmonization of the use of color is appropriate	-	-	3	3
Harmonization of the use of typeface (font) is appropriate	-	-	3	3
The placement of the layout of menu buttons and submenus is consistent / uniform.	-	-	4	4
The placement of text on each material is consistent / uniform	-	-	4	4
The color of the media is interesting	-	-	3	3
The media as a whole is interesting	-	-	4	4
The media as a whole is interactive	-	-	4	4
Mean				3,765

This learning media was created in response to Arbain and Shukor's research, which found that GeoGebra has a good effect on student accomplishment and a positive perception of GeoGebra in terms of enthusiasm, confidence, and motivation [1]. During the COVID-19 pandemic, most students have difficulty studying online [37]-[39]. Highly abstract calculus content makes it difficult for pupils to visualize [15]. As a result, GeoGebra was picked to assist in overcoming the issues since, according to Azaka [25],

GeoGebra can assist in solving mathematical difficulties relating to geometry and algebra. This learning media's content is written in LaTeX and entered into GeoGebra. According to Bahls and Wray, consistent usage of LaTeX appears to bring extra cognitive benefits for pupils [22]. Students can enter graphical equations and investigate how to visualize the concept of derivatives when depicted graphically, making this media interactive with its viewers.

The design of this media required a long time because of the difficulty in programming GeoGebra for the convenience of pupils. The scarcity of available references and lessons was a significant challenge. As a result, an independent exploration of the available tools was conducted. Multiple trials were required to ensure no overlapping portions and that it could operate smoothly to produce a decent show. A nice display makes pupils feel at ease while learning and promotes student interaction with media [8].

GeoGebra is software used to create function graphs and solve other mathematical issues. As a result, GeoGebra's capabilities are not as comprehensive as other software geared toward developing learning material, such as Adobe Flash Player. GeoGebra does not support video or music, so creating instructional material that looks intriguing and interactive with these limited tools is a challenge in and of itself. Despite its limitations, GeoGebra can still be an interactive learning media [8], [19].

This study, like many other studies, has limitations. Other elements that could support the improvement of spatial abilities, such as the ability to engage with other pupils, speak and communicate, and even the acceptability of using this media on other topics, were not taken into account by the teacher-researcher [8]. The study's limitations allow further research on mathematical topics that can be presented through media and educational tools.

4. CONCLUSION

The results of this development research as a whole can be said to be valid, both in the material and media aspects. The validity score level given by the validator for this online learning media is 3.79 in the valid category. This development research results in a valid online learning media using GeoGebra and LaTeX on derivative material.

The online-based GeoGebra is easy for students because they do not need to install GeoGebra software first. However, to open this online-based GeoGebra learning media, you should use a device with a large enough screen, such as a laptop or PC. If the learning media is used on devices that have a small screen, such as smartphones or tablets, it will be difficult to use because it is not specifically designed to be mobile-friendly.

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