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THE DEVELOPMENT OF GEOGEBRA-ASSISTED LEARNING MEDIA BASED ON PROBLEM-BASED LEARNING ON SENIOR HIGH SCHOOL

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ABSTRACT

Students' difficulties in understanding Systems of Linear Equations in Three Variables (SPLTV) are often caused by limited visualization and a lack of contextual learning approaches. The purpose of this study is to develop a Geogebra-assisted learning media based on Problem-Based Learning that is valid and practical, thus, it can support students in learning mathematics. The method used was design research of the development studies type with Gravemeijer's stages, which consist of three phases, but were limited to the second trial phase in the teaching experiment stage. The subjects in this study were students of Class XI-1 at SMAN 2 Cimahi and Class XI-I at SMAN 1 Batujajar. The instruments used were expert validation sheets and student and teacher response questionnaires, which were then analyzed using a Likert scale of 1 to 5. The validation results showed that the Geogebra-assisted learning media based on Problem-Based Learning met the criteria for validity in terms of both content and media aspects. The first and second trial phases indicated that the Geogebra-assisted learning media met the Very Good criteria in terms of practicality based on student and teacher responses. Therefore, this Geogebra-assisted learning media is recommended as an alternative supporting media in mathematics learning, particularly for SPLTV material, as it can help students understand mathematical concepts more clearly, interactively, and contextually.

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INTRODUCTION

Mathematics is one of the disciplines that has experienced rapid development in developed countries. This advancement is driven by the focus of these countries on science and mathematics. If the development of mathematical knowledge progresses as expected, it will result in a high-quality generation in the future. However, over time, various obstacles have emerged in achieving this goal. These challenges must be addressed promptly by the Indonesian

government, particularly in the field of education, especially in the implementation of mathematics learning in schools (Siregar, 2025).

Mathematics is one of the compulsory subjects in Indonesia. Several countries have reported that mathematics poses a challenge for students (Barcelos et al., 2018). However, not everyone realizes the importance of mathematics, as indicated by the large number of students who are still reluctant and afraid to study mathematics (Abadi et al., 2017). Ahyarudin (Utami & Warmi, 2020) stated that the results of a survey revealed that most high school students perceived mathematics as a difficult and intimidating subject.

In mathematics learning, one of the topics taught in senior high school, according to the 2013 curriculum, is Systems of Linear Equations in Three Variables (SPLTV). This topic is introduced in Class X and serves as an extension of Systems of Linear Equations in Two Variables (SPLDV). A system of linear equations in three variables is a set of linear equations that involves three different variables, each raised to the power of one. Problems involving SPLTV can be solved using several methods, including substitution, elimination, a combination of substitution and elimination, and the determinant method (Salaka et al., 2022).

According to A.P. et al. (2020), students' difficulties in learning SPLTV include: (1) a lack of clear understanding of the concepts or definitions of systems of linear equations in three variables; (2) difficulty in identifying variables and formulating SPLTV concepts; (3) challenges in solving contextual problems related to SPLTV; and (4) an inability to conclude SPLTV contextual problems. Similar findings were reported by (Hartinah & Ferdianto, 2019), who observed that many students encountered difficulties in solving SPLTV problems. This was evident from the high number of incorrect answers, including: (1) most students made mistakes when translating word problems into mathematical models; (2) students were confused in selecting appropriate solution methods, even when given the freedom to choose their preferred method; and (3) errors occurred during substitution or elimination steps.

In the current era of technology, mathematics learning is no longer conducted solely through manual methods. The use of technology has had a significant impact on how teachers teach and how students learn mathematics. For instance, mathematical software and applications such as GeoGebra and MATLAB are used to perform calculations, visualize mathematical concepts, and solve problems more efficiently (Barwell, 2018). To address the challenges in learning Systems of Linear Equations in Three Variables, the integration of technology as a supporting tool, particularly ICT-based learning media aligned with instructional models, is highly recommended. One such learning medium that can address these difficulties is Geogebra-assisted learning media based on the Problem-Based Learning model.

According to Hohenwarter (Rahmawati, 2019), GeoGebra is a computer program designed for teaching mathematics, particularly geometry and algebra. GeoGebra enables students to actively construct their understanding of geometric and algebraic concepts. This program allows students to create simple visualizations of geometric concepts, thereby facilitating the discovery, expression, and representation of their mathematical ideas. GeoGebra features multiple representations, including (1) algebraic views, (2) graphical views, and (3) numeric views. These three representations are dynamically interconnected (Yanti et al., 2019). Additional advantages of GeoGebra in mathematics learning, as stated by Laborde, include its capabilities in visualizing mathematical concepts, conducting simulations, and modeling various mathematical situations. These features help students understand and internalize mathematical concepts in a more tangible and concrete manner (Yanti et al., 2019).

Ramadhanti et al., (2022) stated that Problem-Based Learning is a teaching and learning model that utilizes a problem-based approach, which can be adopted by mathematics teachers as an effective solution to enhance students' problem-solving abilities, reasoning, critical thinking,

and creativity, which remain relatively low. According to Sugiyanto (Pratiwi & Setyaningtyas, 2020), the steps of Problem-Based Learning include: (1) orienting the problem by forming groups consisting of 4–5 students; (2) organizing students by guiding them to analyze the case; (3) gathering resources to support case resolution; (4) developing and presenting discussion results through group discussion or presentations; and (5) analyzing and evaluating the process and outcomes of the case resolution.

GeoGebra-assisted learning media based on the Problem-Based Learning model hold significant potential for improving the quality of learning in the SPLTV topic. By integrating the interactive visualizations of GeoGebra with the authentic problem-solving approach of Problem-Based Learning, students can develop a deeper conceptual understanding, stronger problem-solving skills, and higher learning motivation.

Although previous studies have explored the use of GeoGebra or Problem-Based Learning separately in mathematics instruction, such as the study by Suryawan & Permana (2020), which developed an online GeoGebra-based learning media on the topic of curved-surface solid geometry, and the study by Indayanti & Sagala (2023), which implemented a Problem-Based Learning model assisted by GeoGebra, this study offers novelty by explicitly developing a learning media that integrates the interactive features and dynamic visualizations of GeoGebra into each stage of the Problem-Based Learning model for the Systems of Linear Equations in Three Variables (SPLTV) topic in Class X of senior high school.

METHOD

This study used a design research approach of the development studies type, following the Gravemeijer model (Marande & Diana, 2022). As stated by van den Akker (Suryani, 2016), design research is categorized as a type of research and development (R&D), as it involves the development of instructional materials and learning resources. According to Gravemeijer and Eerde (Prahmana, 2017), design research is a research method aimed at developing local instructional theory through collaboration between researchers and teachers to improve the quality of learning. Design research encompasses a structured instructional process that includes designing, developing, and evaluating all learning components, such as instructional designs, learning processes, learning environments, instructional media, teaching materials, and even learning systems. The stages of the Gravemeijer model are illustrated as follows:

Figure 1. Stages of the Gravemeijer Design Research Model

In the preliminary design phase, the media design was validated by content and media experts. The feedback and suggestions provided by the experts were analyzed to determine which parts required revision, serving as the basis for refining the prototype of the learning media. As a result, a GeoGebra-assisted learning media that was valid and practical was obtained. The teaching experiment phase included the first trial, data collection through questionnaires and surveys, product revision, and a second trial. The final phase involved analyzing the learning process data to revise and produce the final version of the learning media ready for implementation.

The research subjects included students of Class XI-I at SMA Negeri 1 Batujajar and Class XI-1 at SMA Negeri 2 Cimahi. Both students and teachers were asked to provide their responses to the developed GeoGebra-assisted learning media through a practical questionnaire. Data collection techniques in this study used several instruments, including validation sheets and response questionnaires. The data analysis technique for the validation sheets and response questionnaires used a Likert scale ranging from 1 to 5. The criteria for assessing the validity and practicality of the product are presented in Table 1 as follows:

Table 1. Criteria for Product Validity and Practicality Assessment

No	Percentage	Criteria
1	81% - 100%	Very Good
2	61% - 80%	Good
3	41% - 60%	Fair
4	21% - 40%	Poor
5	0% - 20%	Very Poor

This study was a Design Research that referred to the stages of the Gravemeijer model: Preliminary Design, Teaching Experiment, and Retrospective Analysis. However, the scope of this study was limited to the second trial phase within the Teaching Experiment stage. This limitation was due to constraints in time, resources, and the primary focus of the study, which was directed toward the development and initial testing of the GeoGebra-assisted learning media based on Problem-Based Learning (PBL) for the Systems of Linear Equations in Three Variables (SPLTV) topic. Therefore, this study did not include long-term effectiveness testing or large-scale classroom implementation.

RESULTS AND DISCUSSION

Results

Preliminary Design Stage

Learning Environment Analysis

The researcher conducted field research and data collection, including interviews with Class X mathematics teachers at SMAN 1 Batujajar, to understand the current teaching methods, student characteristics (including prior knowledge and learning styles), as well as the challenges faced by teachers in delivering the Systems of Linear Equations in Three Variables (SPLTV) topic.

Literature Review

At this stage, the researcher conducted a literature review by examining previously published research articles in accredited journals indexed by SINTA. The review focused on topics related to Problem-Based Learning, the Systems of Linear Equations in Three Variables, and GeoGebra-assisted learning media.

Product Design

At this stage, the researcher developed the product design. The product to be developed was a GeoGebra-assisted learning media based on the Problem-Based Learning model for the SPLTV topic in Class X of senior high school.

Expert Validation

After designing the product, the GeoGebra-assisted learning media underwent expert validation. The validation of the GeoGebra-assisted learning media prototype (Prototype I) was carried out by three experts: one subject matter expert from a university, one media expert from a university, and one high school mathematics teacher. The validators included: (1) Risma

Amelia, M.Pd., a Mathematics Education lecturer at IKIP Siliwangi. The validation process was conducted face-to-face on January 30, 2025; (2) Martin Bernard, M.Pd, a Mathematics Education lecturer and IT specialist in programming and mathematical coding at IKIP Siliwangi. The validation process was conducted face-to-face on March 14, 2025; (3) Dra. Tiktik Gantinah, M.Pd, a senior civil servant teacher at SMAN 1 Batujajar. The validation process was conducted face-to-face on February 4, 2025.

The overall results of the validation questionnaire criteria assessed by the validators are presented in Table 2 below:

Table 2. Results of the Material Validation Questionnaire

No	Validator	Material Quality	
		Percentage	Criteria
1	Risma Amelia, M.Pd	66%	Good
2	Dra. Tiktik Gantinah, M.Pd	79%	Good
	Total	145%	
	Average	72.5%	Good

Table 2 shows that the average percentage is 72.5%, which indicates that, according to the material experts, the level of validity of the GeoGebra-assisted learning media falls under the Good category.

Table 3. Results of Media Validation Questionnaire

Validator	Media Quality	
	Percentage	Criteria
Martin Bernard, M.Pd	76%	Good

Table 3 shows that the average percentage is 76%, which indicates that, according to the media expert, the level of validity of the GeoGebra-assisted learning media also falls under the Good category.

Revised Product Draft

At this stage, the researcher revised the design of the Prototype I learning media based on the feedback provided by the experts to produce a product draft ready for testing. Prototype I is presented in the following figures:

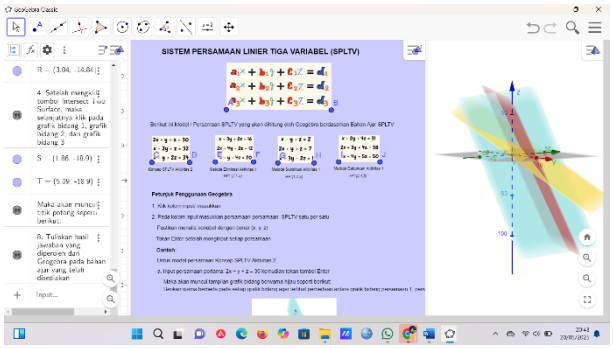

Figure 2. Cover and Introductory Page

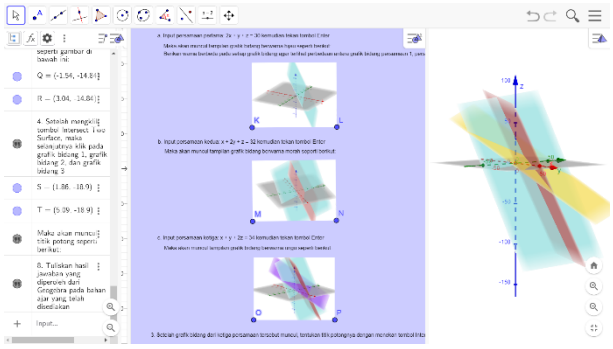

Figure 3. Visualization Steps of SPLTV in the Form of Plane Graphs

Several components were revised following the expert validation process, including the cover and introductory pages, the SPLTV visualization section, illustrations and problem scenarios, the addition of Problem-Based Learning phases, and a reduction in the number of learning sessions. The cover and introductory pages of Prototype I were modified to place greater emphasis on initial stimulation or recalling the prerequisite topic of Systems of Linear Equations in Two Variables (SPLDV), to support a better understanding of SPLTV concepts. The SPLTV visualization section was revised to include not only graphical representations of planes but also visualizations involving intersecting lines and points of intersection, which serve as the solutions to SPLTV problems. Illustrations and problem scenarios were added based on the instructional materials and student worksheets (LKPD). Additional phases or steps of the Problem-Based Learning model were incorporated to help guide students in solving SPLTV problems. The original media, which consisted of four pages for four meetings, was condensed into two pages for two meetings: the first page introduces the concept, while the second page focuses on visualizing SPLTV using plane graphs, intersecting lines, and points of intersection as the solutions. The revised GeoGebra-assisted learning media based on the Problem-Based Learning model are shown in the following figures:

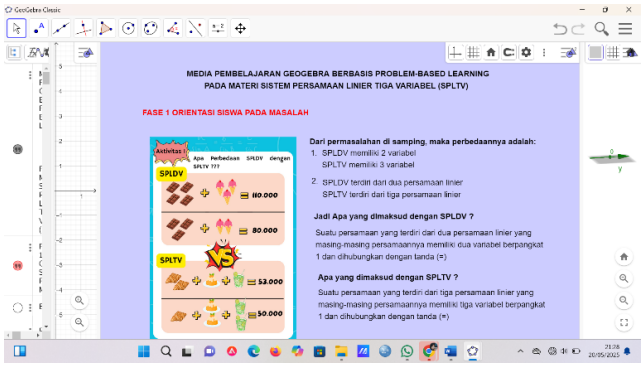

Figure 4. Revised Concept of SPLTV

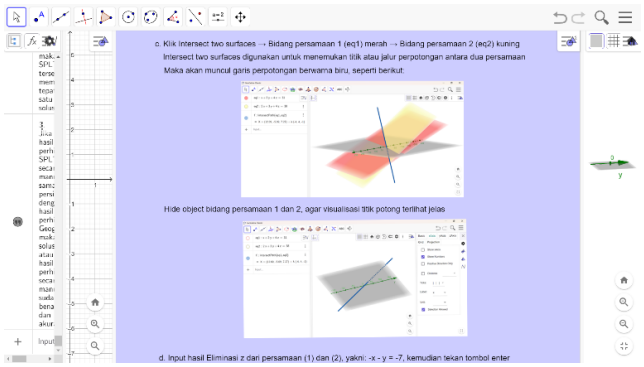

Figure 5. Revised Visualization of SPLTV Lines and Points of Intersection

Teaching Experiment Phase

First Trial

In this phase, Prototype II was administered to six students from Class XI-1 of SMAN 2 Cimahi with varying levels of ability, along with one mathematics teacher. This activity was conducted on May 2, 2025, to observe student and teacher responses to the GeoGebra-assisted learning media. During this stage, the teacher suggested that the GeoGebra-assisted learning media should be made available in an online file format so that students could review the material independently and from any location. After considering the feedback, the researcher decided to proceed to the second trial phase.

In the next phase, students and the teacher were given a response questionnaire to evaluate the practicality of the GeoGebra-assisted learning media. The results are presented in Tables 4 and 5.

Table 4. Student Response Questionnaire Results – First Trial

No	Student Name	Percentage	Criteria
1	R1	98%	Very Good
2	R2	87%	Very Good
3	R3	76%	Good
4	R4	87%	Very Good
5	R5	92%	Very Good
6	R6	88%	Very Good
7	R7	83%	Very Good
8	R8	91%	Very Good
9	R9	89%	Very Good
10	R10	91%	Very Good
Total		882%	Very Good
Average		88%	

Table 4 shows that the average percentage was 88%, indicating that, according to the students, the practicality level of the GeoGebra-assisted learning media falls into the Very Good category.

Table 5. Teacher Response Questionnaire Results – First Trial

No	Teacher Name	Percentage	Criteria
1	RE	90%	Very Good

Table 5 shows that the average percentage was 90%, indicating that, according to the teacher, the practicality level of the GeoGebra-assisted learning media falls into the Very Good category.

Second Trial

In this phase, Prototype III was tested on 34 students from Class XI-I and a mathematics teacher at SMAN 1 Batujajar. During this phase, no suggestions or feedback were given by the teacher or students. At the end of the trial, both the teacher and students were given questionnaires to assess the practicality of the GeoGebra-assisted learning media. The results are presented in Tables 6 and 7.

Table 6. Student Response Questionnaire Results – Second Trial

No	Student Name	Percentage	Criteria
1	R1	69%	Good
2	R2	87%	Very Good
3	R3	68%	Good
4	R4	69%	Good
5	R5	81%	Very Good
6	R6	85%	Very Good
7	R7	78%	Good
8	R8	94%	Very Good
9	R9	92%	Very Good
10	R10	89%	Very Good
11	R11	87%	Very Good
12	R12	88%	Very Good
13	R13	93%	Very Good
14	R14	81%	Very Good
15	R15	80%	Good
16	R16	86%	Very Good
17	R17	81%	Very Good
18	R18	83%	Very Good
19	R19	84%	Very Good
20	R20	80%	Good
21	R21	78%	Good
22	R22	77%	Good
23	R23	87%	Very Good
24	R24	78%	Good
25	R25	80%	Good
26	R26	82%	Very Good
27	R27	81%	Very Good
28	R28	81%	Very Good
29	R29	80%	Good
30	R30	80%	Good
31	R31	80%	Good
32	R32	80%	Good
33	R33	80%	Good
34	R34	80%	Good
Total		2782%	Very Good
Average		82%	

Table 6 shows that the average percentage was 82%, indicating that, according to the students, the practicality level of the GeoGebra-assisted learning media falls into the Very Good category.

Table 7. Teacher Response Questionnaire Results – Second Trial

No	Teacher Name	Percentage	Criteria
1	RH	87%	Very Good

Table 7 shows that the average percentage was 87%, indicating that, according to the teacher, the practicality level of the GeoGebra-assisted learning media falls into the Very Good category.

Discussions

This study aimed to address students' difficulties in understanding the SPLTV, which are often caused by limited visualization and a lack of contextual learning approaches. The research findings directly responded to the initial objective of developing a learning media that is both valid and practical. During the expert validation phase, the media showed "Good" quality in terms of both content and media aspects. This indicates that the learning media prototype met the feasibility standards in terms of content and visual design, which is a crucial step in developing effective instructional media. The validators, including a subject matter expert, a media (IT) expert, and a senior teacher, provided comprehensive feedback to ensure that the media aligned with curriculum requirements and student characteristics. This finding is in line with the results of the study by Winarni & Hidayat (2018), which showed that the mathematics comic learning media based on Problem-Based Learning developed using Manga Studio and GeoGebra falls into the category of good quality media, as it meets the criteria of validity, practicality, and effectiveness.

The practicality of the GeoGebra-assisted learning media based on the Problem-Based Learning model was shown in both the first and second trial phases, as reflected in the average percentage of student and teacher responses. This indicates that the media was easy to use and well-received by its users. The positive responses from students and teachers confirmed that this learning media can be effectively integrated into the instructional process. This finding is in line with the results of the study by Komala Sari et al., (2016), which showed an improvement in student responses before and after using GeoGebra assisted learning media. Feedback from the first trial, such as the suggestion to provide the media in an online format to support independent learning, highlighted the potential for adapting the media for more flexible learning. This finding is consistent with the study by Suryawan & Permana (2020), which showed that an online GeoGebra-based learning media on the topic of curved-surface solid geometry met the criteria of validity, practicality, and effectiveness in improving the conceptual understanding of mathematics among students of Class IX in junior high school.

The integration of GeoGebra visualizations and the Problem-Based Learning model has the potential to enhance students' conceptual understanding, problem-solving skills, and learning motivation. The revised media design, including the addition of line and intersection point visualizations as solutions to SPLTV problems and the adjustment of the learning session duration, further strengthened the media's potential to support students in understanding SPLTV concepts. This finding is in line with the study by Indayanti & Sagala (2023), which concluded that the implementation of the Problem-Based Learning model assisted by GeoGebra can improve students' mathematical creative thinking skills. This is in line with the findings of Sugiarni et al., (2018), which showed that mathematics learning using the Problem-Based Learning model assisted by GeoGebra can improve student's mathematical spatial abilities in geometry material.

CONCLUSION

This study developed a GeoGebra-assisted learning media based on the Problem-Based Learning (PBL) model for the Systems of Linear Equations in Three Variables (SPLTV) topic, which is valid and practical. The media's validity was demonstrated through expert evaluations of both content and media aspects, which met the criteria of Good, while its practicality was confirmed through trial phases involving students and teachers, which met the Very Good criteria.

The media effectively visualized SPLTV concepts dynamically and interactively, and provided a contextual learning experience through a problem-based approach. Therefore, this media is recommended as an alternative supporting tool for mathematics instruction, as it can enhance students' conceptual understanding and engagement in learning.

This study was limited to the second trial phase. Thus, further research is recommended to examine the effectiveness of this media on a broader scale and over a longer period.

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