



Validity of STEAM-Based Learning Media on Circle Equation Topics to Support Students' Conceptual Understanding

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ABSTRACT

Purpose of the study:

The purpose of this study is to develop and examine the validity STEAM-based mathematics learning media for the topic of circle equations to support and improve senior high school students' conceptual understanding.

Methodology:

This study employed a research and development (R&D) approach using the 4-D model, consisting of Define, Design, Develop, and Disseminate. However, this research was limited to the Develop stage, particularly expert validation of the developed media. The research instruments included expert validation sheets, while the media was developed using Articulate Storyline and GeoGebra. The data were obtained through a literature review and expert judgment.

Main Findings:

The developed STEAM-based learning media obtained an average validity score of 82.5%, which falls into the very valid category. This result indicates that the media is feasible in terms of content accuracy, interface design, usability, and clarity of language and symbols.

Novelty/Originality of this study:

This study introduces a STEAM-based mathematics learning media for the topic of circle equations to support students' conceptual understanding. Its novelty lies in the structured integration of STEAM components with dynamic visualization and interactive design, offering an innovative instructional approach to enhance students' conceptual understanding in analytic geometry.

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1. INTRODUCTION

Mathematics learning is a process aimed at shaping students' systematic and logical thinking patterns as well as developing mathematical abilities, particularly in conceptual understanding [1]; [2]. Each mathematical topic taught in schools contains interconnected concepts; therefore, strong conceptual understanding is essential for constructing meaningful knowledge. Students are considered to have conceptual understanding when they are able to explain mathematical ideas in their own words,

recognize relationships among concepts, and apply them in various situations [3]; [4]. Learning mathematics is not merely about memorizing formulas, but about understanding the underlying meaning in order to solve problems flexibly [5]; [6]. This aligns with the OECD (2012) recommendation that mathematics learning should be conceptual and contextual so that students are able to apply mathematical concepts in real-life situations [7]; [8]

However, in practice, students' mathematical conceptual understanding remains suboptimal, particularly in the topic of circle equations. Previous studies involving Grade XI students indicate that this topic often poses conceptual difficulties because it is part of analytic geometry, which integrates algebraic and geometric concepts [9]; [10]. Students frequently experience difficulties in transforming the general form into the standard form of a circle equation, determining the center and radius, and understanding the relationship between the equation and the graphical representation of a circle [11]; [12]. Several studies have also reported misconceptions, such as errors in identifying the radius or determining the position of a point relative to a circle. These difficulties are further compounded by the abstract nature of the material, which requires strong visualization skills. In addition, conventional teaching practices that still dominate and the limited use of interactive visual media contribute to students' low conceptual understanding [13]; [9].

To address these challenges, a learning approach that integrates conceptual understanding, technology, and exploratory student activities is required. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is an integrative learning framework that emphasizes interdisciplinary connections to foster conceptual understanding, creativity, and higher-order thinking skills. STEAM-based learning encourages students to connect mathematical concepts with exploration, design processes, and contextual problem solving supported by technology, making learning more meaningful and applicable [14]; [15]. In the context of mathematics education, STEAM approaches have been shown to enhance conceptual understanding, student engagement, and critical thinking skills through the integration of visualization, digital technology, and project-based activities [16]; [17].

The implementation of STEAM approaches in mathematics learning requires appropriate technological support and instructional media. The integration of digital technology, dynamic mathematical software, and interactive visual design enables students to construct concepts in an exploratory and reflective manner [18]; [19]. Interactive digital learning media have also been proven effective in helping students visualize abstract concepts, increasing engagement, and supporting deeper conceptual understanding [20]; [21]. In this context, GeoGebra supports the Science and Mathematics components through dynamic visualization and mathematical modeling. GeoGebra is widely recognized as an effective tool for facilitating students' understanding of geometric concepts by linking dynamic visual representations with algebraic forms [11]; [22]. Meanwhile, Articulate Storyline supports the Technology, Engineering, and Arts components through media design, user interaction, and instructional interface development. Articulate Storyline enables more engaging learning experiences through the integration of animations, videos, quizzes, and interactive simulations, which can enhance students' motivation, participation, and conceptual understanding [23]; [24]. Therefore, the development of learning media assisted by Articulate Storyline and GeoGebra represents a concrete implementation of STEAM-based mathematics learning.

Thus, the development of STEAM-based mathematics learning media is highly urgent as an effort to overcome students' difficulties in understanding the concept of circle equations. In addition to improving conceptual understanding and active student participation, this media also supports the achievement of 21st-century competencies, including technological literacy, creativity, and critical thinking skills. Furthermore, this learning media can serve as an innovative alternative for teachers in providing learning experiences that are relevant to curriculum implementation and technological advancements.

2. RESEARCH METHOD

This study employed a research and development (R&D) approach using the 4-D development model proposed by Thiagarajan. The model consists of four development stages: Define, Design, Develop, and Disseminate [25]. In this study, all four stages are described; however, the research implementation was limited to the Develop stage, particularly expert validation of the media product. Therefore, this study focused on examining the validity of the developed learning media.

At the Define stage, a needs analysis was conducted through literature review. This activity aimed to identify curriculum demands, student characteristics, learning difficulties on circle equation topics, and the need for interactive media that can support conceptual understanding. At the Design stage, the initial prototype of the learning media was designed. This stage included preparing the content structure, determining the STEAM integration framework, designing the interface and navigation flow, developing student worksheets (LKPD), and constructing the research instruments in the form of expert validation sheets. At the Develop stage, the media prototype was realized into a functional product using Articulate Storyline and GeoGebra. After the product was developed, expert validation was conducted to assess its feasibility in terms of content accuracy, interface design, usability, and clarity of language and symbols. Suggestions from validators were then used as the basis for revising the product. At the Disseminate stage, the product should ideally be implemented and distributed on a broader scale. However, this stage was not carried out in the present study due to time and research scope limitations. Therefore, the study was limited to the development and expert validation stage.

The product developed in this study was STEAM-based mathematics learning media on the topic of circle equations for Grade XI senior high school students. The product trial consisted of expert validation assessment. The validity assessment was conducted by two expert validators, both lecturers in Mathematics Education at Malang State University. Learning media and supporting instruments were deemed valid if they reached the valid or very valid category based on the validation coefficient classification presented in Table 1.

Table 1. Classification of Validity Scores	
Percentage Score (%)	Criteria
81 - 100	Very Valid
61 - 80	Valid
41 - 60	Fairly Valid
21 - 40	Less Valid
0 - 20	Not Valid

The validity score was calculated using the following formula:

$$\text{Validity Percentage} = \frac{\text{Total score obtained}}{\text{Maximum score}} \times 100\%$$

3. RESULTS AND DISCUSSION

Result Research

The results of the development of the learning media were obtained through three stages, namely Define, Design, and Develop.

3.1. Define Stage

The define stage was conducted to identify learning needs and formulate the problems underlying the development of the learning media. In this study, the analysis at the define stage was carried out entirely through a literature review of the curriculum, students' characteristics, and previous studies related to learning the topic of circle equations. The literature review indicated that the topic of circle equations is often considered difficult because it requires an understanding that integrates geometric and algebraic concepts [26]; [27]. In addition, existing learning media have not fully provided the visual and interactive explanations needed to support students' understanding [13]; [28]. The literature analysis also revealed that students need learning media that can be used independently, present materials in a structured and easily understandable manner, include visualizations, are practical to use, and provide exercises to assess understanding [29]; [22]. Therefore, an interactive STEAM-based learning media was developed to support students' understanding of the topic of circle equations.

3.2. Design Stage

The design stage aimed to produce an initial prototype of the learning media through several main activities, including the preparation of validation instrument, the selection of learning media platforms, the development of student worksheets (LKPD) as supporting learning activities, and the

design of the initial interface and interactive learning flow. At this stage, the STEAM-based learning media was designed as a visualization and interaction tool to help students understand the concept of circle equations. The media consists of several frames systematically arranged based on predetermined learning syntax, starting from an introduction, material presentation, exploration using GeoGebra, interactive exercises, to evaluation and reflection. This design ensures that each component of the media supports the achievement of learning objectives in a structured and continuous manner.

3.3. Develop Stage

At the development stage, the product was developed based on the initial design formulated in the previous stage. The development process included creating media components, arranging navigation flow, integrating visual and interactive elements, and adjusting the learning materials. At this stage, the learning media was realized in a concrete form so that the entire initial design could be tested for its suitability. Several displays of the developed learning media are shown in the following figures:



Figure 1. Main Interface and User Guide of the Media



Figure 2. Main Menu Interface of the Media



Figure 3. GeoGebra exploration menu interface

After the media had been fully developed, expert validation was conducted to examine the validity of the product before proceeding to field trials. The validation process covered four aspects: content accuracy, interface design, media usability, and clarity of language and symbols. The validation

was carried out by two expert validators with competencies in Mathematics Education. The complete results of the validation are presented in Table 3.

Table 2. Media Validation Results

Aspect	Mean Score	Criteria
Content Accuracy	80%	Valid
Interface Design	87.5%	Very Valid
Media Usability	75%	Valid
Language and Symbols	87.5%	Very Valid
Average	82.5%	Very Valid

Based on the expert validation results, the average score obtained was 82.5%, which falls into the very valid category. This indicates that the developed STEAM-based learning media has met the feasibility standards in terms of content, visual design, usability, and clarity of mathematical language and symbols. Therefore, the media is considered suitable to proceed to the next stage, namely limited field trials, to examine its practicality and effectiveness in supporting students' conceptual understanding.

Discussion

The development of STEAM-based mathematics learning media on the topic of circle equations showed positive results in terms of validity, demonstrates very positive results in terms of validity and practicality. The expert validation results, which reached the very valid category with a score of 82.5%, indicate that the developed media meets feasibility standards in terms of content accuracy, visual design, media usability, and the clarity of mathematical language and symbols. These findings suggest that the media has been systematically designed and aligned with the characteristics of mathematics learning at the senior high school level, particularly for the topic of circle equations.

The high validity score in the content aspect indicates that the presentation of circle equation concepts in the media is consistent with curriculum demands and learning objectives. This is particularly important given that circle equations are part of analytic geometry, which requires an integrated understanding of algebraic and geometric concepts and often poses conceptual difficulties for students [26]; [4]. The integration of GeoGebra in the learning media allows students to directly observe the dynamic relationship between algebraic equations and graphical representations of circles, thereby reducing the abstract nature of the material. This finding is consistent with previous studies by [30] and [22], which reported that GeoGebra is effective in supporting conceptual understanding through interactive and exploratory visualization.

In addition, the high validity scores for the visual design as well as the use of mathematical language and symbols indicate that the media has been developed with clear visuals, structured navigation, and appropriate mathematical terminology and notation. These aspects support the characteristics of STEAM-based learning, which emphasizes the integration of visual elements, technology, and mathematical representations to foster holistic conceptual understanding [14]; [16]. Thus, the developed media is not only content-feasible but also facilitates more meaningful and reflective learning processes.

Overall, the validation results show that the developed STEAM-based learning media is feasible as a product of educational media development. However, since this study was limited to the development and expert validation stage, further research is needed in the form of field trials to examine the practicality and effectiveness of the media in supporting students' conceptual understanding.

4. CONCLUSION

Based on the results of the study, it can be concluded that the STEAM-based mathematics learning media on the topic of circle equations was successfully developed using the 4-D model, covering the Define, Design, Develop, and Disseminate framework, although the implementation of this research was limited to the Develop stage. The expert validation results showed an average score of 82.5%, which is categorized as very valid. This indicates that the developed media is feasible in terms of content accuracy, interface design, usability, and clarity of language and symbols. Therefore, the developed media can be regarded as a valid learning product and is appropriate to be continued to the

next stage, namely limited field trials, in order to examine its practicality and effectiveness in supporting students' conceptual understanding.

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