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Interactive Ethnomathematics-Based Learning Media: Development of Articulate Storyline 3 to Improve Mathematical Communication Skills

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ABSTRACT

Mathematical communication skills are essential for critical thinking and conceptual understanding, yet they remain low among students, particularly in connecting mathematics to real-life contexts. This study aims to develop interactive ethnomathematics-based learning media using Articulate Storyline 3 and to examine its feasibility and potential in improving students' mathematical communication skills. The novelty of this study lies in integrating local cultural contexts from Kuningan Regency into interactive digital media designed specifically to facilitate mathematical communication. This research employed an R&D approach with the ADDIE model (analysis, design, development, implementation, evaluation). The subjects were 23 tenth-grade students of MAN 1 Kuningan. Instruments included expert validation sheets, mathematical communication tests, and response questionnaires. Expert validation showed very high feasibility: material experts 93.21% and media experts 96.92%. Practicality was also very high: student responses 92.85% and teacher responses 96.66%. Effectiveness was demonstrated by an average N-Gain of 0.55 (medium category). The highest improvement occurred in explaining calculation results in written form (N-Gain 0.78, high category), while conveying mathematical contexts and explaining concepts achieved N-Gains of 0.52 and 0.50 (medium category). The main contribution is empirical evidence that integrating ethnomathematics into Articulate Storyline 3 media can be effectively designed, validated, and implemented to improve mathematical communication skills, while offering a contextual media development model adaptable to other local cultures. These findings confirm that interactive ethnomathematics-based learning media are feasible, practical, and effective as an innovative alternative to strengthen students' mathematical communication skills.

Keywords: Articulate Storyline 3, Communication Skills, Ethnomathematics, Interactive Learning Media, Mathematical.

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Introduction

Mathematical communication skills are considered crucial competencies in the 21st century because they enhance critical thinking, support problem-solving abilities, and enable individuals to convey mathematical ideas effectively through oral, written, symbolic, and visual forms (Saputra, 2024). Theoretically, the development of mathematical communication skills requires structured attention to how students comprehend and produce mathematical language. Habala & Demlova (2019) emphasized that teaching comprehension of mathematical language is fundamental, as students often struggle not only with calculation but also with the syntax and

semantics of mathematical expressions. Furthermore, Cuevas (1991) argued that communication skills in mathematics must be explicitly developed, particularly for students who face linguistic or cultural barriers, by providing opportunities to explain, justify, and discuss mathematical ideas in multiple forms. These foundational perspectives underscore that communication is not an automatic byproduct of learning mathematics but requires intentional instructional design**.** The advancement of digital technology has substantially transformed mathematics learning practices, especially through the integration of interactive instructional media (Azizah et al., 2024). However, various studies and educational evaluation reports indicate that students' mathematical communication skills in Indonesia remain relatively low, especially in explaining their thinking processes and connecting mathematical concepts to real-life contexts (Purwati, 2020; Shafira et al., 2021). This problem is not unique to Indonesia; international research has consistently documented similar challenges. Ya-Amphan et all (2024) conducted a comparative study across Japan, Laos, and Thailand, finding that students' mathematical communication skills remain a persistent challenge despite varying educational systems. Moreover, Ndagijimana et al. (2024) reported that students in socio-cultural learning contexts struggle to articulate mathematical concepts without adequate technological scaffolding, as demonstrated in their quasi-experimental study involving 279 secondary students in Rwanda. This condition is further exacerbated by the dominance of procedural-oriented instruction and the use of conventional learning media that provide limited opportunities for interaction, exploration, and meaningful knowledge construction for students (Rakhman et al., 2024).

A number of earlier studies have investigated the design and implementation of interactive learning media in mathematics education. Research by Wahidin (2025) and Fiani et al. (2024) showed that multimedia-based interactive media can improve conceptual understanding through simultaneous processing of visual and verbal information. Other studies developed Articulate Storyline-based learning media and evealed that the learning media met the criteria of validity, practicality, and effectiveness in enhancing students' achievement in mathematics (Pradyani & Paramita, 2024; Mufidah & Khoiri, 2021; Amelia & Mintohari, 2024). The practicality of Articulate Storyline 3 in mathematics instruction has likewise been recognized by international research beneficial for the learning process. Sari & Qohar (2023) developed Articulate Storyline 3-based media for cube material, obtaining an average student positive response of 93.35% and media expert validity of 3.6 (valid category). More recently, Sari et al. (2025) reported that Articulate Storyline 3-based learning media achieved very high validity and practicality in improving students' critical thinking skills and learning interest in statistics, with the study involving both experimental and control classes. The international collaboration between Indonesian

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and Vietnamese researchers in this study strengthens the external validity of Articulate Storyline 3's effectiveness across different educational contexts.

Furthermore, research on ethnomathematics-based approaches has demonstrated that integrating local cultural contexts can increase student engagement and foster positive attitudes toward mathematics (Serepinah & Nurhasanah, 2023). This finding is strongly supported by international research. A study published in the Journal on Mathematics Education by Rodríguez-Nieto et al. (2023) proposed principles for creating interactive mathematical activities that combine reasoning and ethnomathematics, showing that these approaches can strengthen students' abilities to justify arguments, evaluate others' ideas critically, and draw logical conclusions. Furthermore, Nugroho et al (2025) carried out a quasi-experimental study focusing on ethnomathematics-based digital books designed for teaching similarity and congruence concepts, the findings indicated that the experimental group obtained a mean post-test score of 78.6 compared to 68 in the control class, with 74% learning completion. This study showed an improvement in students' mathematical communication abilities, with the average score rising from 60 on the pre-test to 78.6 on the post-test. Agoestanto et al. (2023) similarly found that e-learning assisted by communication media with an urban ethnomathematics approach was effective for students' mathematical representation abilities. Rizal et al. (2021) specifically reported that ethnomathematics-based learning contributed to improvements in secondary school students' mathematical communication skills. Studies on the development of ethnomathematics-based digital media have also shown that integrating local culture into digital learning media can enhance students' motivation and understanding (Sukiastini, 2024; Djarwo et al., 2025).

Despite these advances, several limitations remain unaddressed in previous research. First, most studies on interactive media development (Wahidin, 2025; Fiani et al., 2024; Pradyani & Paramita, 2024) have not specifically focused on improving mathematical communication skills as the primary objective, instead emphasizing general cognitive learning outcomes. This gap is significant in the international literature as well. While Anggraeni et al. (2023) designed Android-based interactive learning media with the assistance of Articulate Storyline 3 to investigate students' mathematical literacy skills, and Maure & Jenahut (2025) created ethnomathematics-based learning media with Articulate Storyline 3 to enhance students' conceptual understanding of calculus, neither study explicitly focused on mathematical communication skills as the primary outcome variable. Munir et al. (2023) developed an Algebra-Ethnomathematics integrated e-module for Luwu culture, but their focus remained on general algebraic understanding rather than specific communication indicators. Second, ethnomathematics research (Serepinah & Nurhasanah, 2023; Rizal et al., 2021) has

often been implemented through conventional learning tools or worksheets, limiting the potential of digital technology to optimally facilitate interaction and mathematical communication. Third, the use of Articulate Storyline 3 in mathematics learning remains relatively limited, particularly in studies that systematically integrate ethnomathematical content into interactive learning design for enhancing mathematical communication skills.

Unlike previous studies, the present research explicitly combines three elements that have not been integrated before: (1) the ethnomathematics approach based on Kuningan Regency local culture, (2) interactive learning media developed using Articulate Storyline 3, and (3) a specific focus on improving students' mathematical communication skills. To date, no prior study has systematically integrated these three components into a single learning media product.

The limited level of students' mathematical communication abilities is reinforced by empirical evidence. A preliminary study conducted at MAN 1 Kuningan through observation and interviews with mathematics teachers revealed that more than 70% of tenth-grade students had difficulty explaining trigonometric concepts using their own words and connecting these concepts to real-life contexts. Furthermore, the average score of students' mathematical communication skills on a pre-test administered to 23 students was only 12 out of a maximum score of 30, with particularly low performance on indicators of explaining mathematical concepts (average score 9.09) and conveying mathematical contexts (average score 10.48). These results highlight the pressing need for innovative instructional media capable of supporting and enhancing students' mathematical communication skills.

One approach considered relevant for bridging the gap between mathematical concepts and students' real-life experiences is ethnomathematics (Khaerani et al., 2024). This approach views mathematics as a cultural product that develops through social practices, allowing mathematics learning to be contextualized through local cultural values, activities, and artifacts (Siregar et al., 2024). Meanwhile, the use of technology-based interactive learning media, such as Articulate Storyline 3, enables the presentation of learning materials that are visual, adaptive, and responsive to student interaction (Ali et al., 2024).

The proposed solution in this study is the development of interactive ethnomathematics-based learning media using Articulate Storyline 3. The media were designed by integrating local cultural contexts from Kuningan Regency into interactive activities that encourage students to express, represent, and discuss mathematical ideas. This combination represents a strategic opportunity to develop

contextual and interactive mathematics instruction that is suited to the characteristics and learning needs of the digital generation (Gusteti, 2024; Ramadhani et al., 2025).

Considering these factors, the present study seeks to design interactive ethnomathematics-based learning media through the use of Articulate Storyline 3 and to investigate its feasibility as well as its potential effectiveness in enhancing students' mathematical communication abilities. The research applies a research and development methodology that includes systematic phases of analysis, design, development, implementation, and evaluation. Accordingly, this study is expected to contribute both theoretically and practically to the advancement of contextual and interactive mathematics instruction aimed at strengthening students' mathematical communication skills.

Methods

This research applied a research and development (R&D) method integrated with a descriptive one-group pretest–posttest design (analyzed using N-Gain to determine the category of improvement, without inferential statistical testing). Ethnomathematics-based interactive learning media using Articulate Storyline 3 and examining its feasibility and potential in improving students' mathematical communication skills. The development model followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) (Pitriani et al., 2021), with each stage elaborated methodologically as follows: (1) Analysis: needs assessment through observation, interviews, and curriculum review; (2) Design: creating flowcharts and storyboards; (3) Development: producing media using Articulate Storyline 3 followed by expert validation; (4) Implementation: pretest, three meetings of media use, and posttest; (5) Evaluation: analysis of validity, practicality, and effectiveness. The development model was structured procedurally through several stages, namely needs analysis, design, development, implementation, and evaluation (Pitriani et al., 2021). This design was chosen to ensure that the developed media corresponded with instructional requirements, learner characteristics, and the needs of contextual and interactive mathematics instruction (Figure 1).

Research Subjects

The subjects of this study were 23 tenth-grade students of MAN 1 Kuningan, consisting of 12 female and 11 male students aged 15-16 years with an average prior mathematics score of 68.5 (on a scale of 0-100). Participants involved in the field trial stage were selected purposively based on the following criteria: students had completed prerequisite material for trigonometry, had access to digital devices (smartphones or laptops), and were recommended by the mathematics teacher as representing varying ability levels in mathematical communication skills. In addition

to students, this study also involved mathematics teachers and expert validators consisting of material experts and media experts who provided evaluations and feedback on the developed learning media.

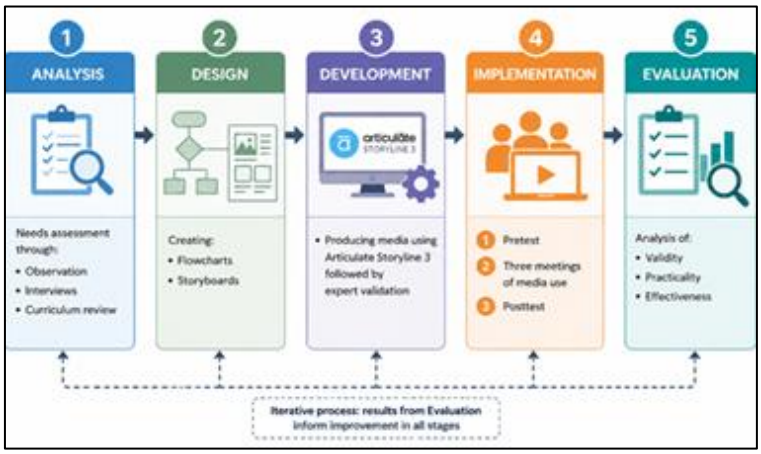

Figure 1. ADDIE instructional design model

Research Instruments

The instruments used in this study consisted of several types. First, validation sheets were used to assess the feasibility of the learning media in terms of content, instructional design, language, and visual appearance, with validity criteria referring to Table 1.

Table 1. Validity Criteria

Average Percentage of Validation Scores	Criteria
80% < score ≤ 100%	Very Valid
60% < score ≤ 80%	Valid
40% < score ≤ 60%	Moderately Valid
20% < score ≤ 40%	Invalid
0% < score ≤ 20%	Very Invalid

Source: Hodiyanto et al. (2020)

Second, a mathematical communication skills test was administered as a pretest and posttest to measure students' abilities before and after using the learning media. The test consisted of three essay questions developed based on three indicators of mathematical communication skills: (1) the ability to convey mathematical contexts using language, symbols, ideas, or mathematical models including pictures, diagrams, or real objects; (2) the ability to explain mathematical concepts, situations, and relationships using one's own language in written form; and (3) the ability to explain the results of mathematical calculations in written form. The test instruments were

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validated by two expert validators (mathematics lecturers and teachers) to ensure content validity. Based on expert judgment, all test items were declared valid and appropriate for measuring students' mathematical communication skills (Table 1). Third, a student response questionnaire was used to determine the practicality and attractiveness of the learning media, with practicality criteria referring to Table 2. All instruments were validated by experts prior to their use in the study.

Table 2. Practicality Criteria

Average Percentage of Practicality Scores	Criteria
80% < score ≤ 100%	Very Practical
60% < score ≤ 80%	Practical
40% < score ≤ 60%	Moderately Practical
20% < score ≤ 40%	Impractical
0% < score ≤ 20%	Very Impractical

Source: Hodiyanto et al. (2020)

Research Procedures

The procedures for developing the ethnomathematics-based interactive learning media were carried out through systematic stages based on the ADDIE model, namely needs analysis, design, development, implementation, and evaluation (Pitriani et al., 2021; Hidayat & Muhamad, 2021). The needs analysis stage was carried out to determine existing learning challenges and students' needs concerning mathematical communication skills. Activities at this stage included observations of mathematics learning processes at MAN 1 Kuningan, interviews with mathematics teachers, and analyses of curriculum documents and learning tools used. The findings of this analysis served as the basis for determining the learning material, ethnomathematical context, and characteristics of the learning media to be developed. The design stage aimed to develop the initial design of the learning media. This stage involved formulating learning objectives, selecting curriculum-aligned materials, and determining ethnomathematical contexts relevant to students' environments and cultures. In addition, flowcharts and storyboards of the learning media were developed as references for creating interactive media using Articulate Storyline 3.

The development stage involved producing the interactive learning media based on the established design. The media were developed using Articulate Storyline 3 by integrating ethnomathematical elements into learning materials, sample problems, exercises, and interactive activities. During this stage, the developed media underwent validation by both subject-matter experts and media experts to evaluate its feasibility regarding content accuracy, instructional aspects, language quality, and visual design. The recommendations and input provided by the validators were subsequently

applied to revise and enhance the media. The implementation stage involved applying the revised learning media in mathematics learning activities at MAN 1 Kuningan. During this stage, students used the interactive learning media in the learning process, while researchers and teachers observed student engagement and the implementation of instruction. Data were also collected through the administration of pre-tests and post-tests to measure students' mathematical communication skills. The evaluation stage was conducted to assess the feasibility and effectiveness of the developed learning media. Evaluation was based on expert validation results, student responses to the use of the media, and improvements in students' mathematical communication skills as indicated by pre-test and post-test results. The evaluation results were used to draw conclusions regarding the quality of the learning media and its potential to enhance students' mathematical communication skills.

Data Collection Techniques

Data collection techniques in this study included several methods. Validation data were obtained through assessment sheets completed by expert validators. Data on students' mathematical communication skills were collected through pre-tests and post-tests. Data on student responses to the learning media were obtained through questionnaires administered after the learning process using the media. In addition, classroom observations were conducted to support and strengthen the quantitative data obtained.

Data Analysis Techniques

The data were analyzed through both quantitative and qualitative methods. Quantitative data obtained from validation instruments and student response questionnaires was processed using descriptive statistical techniques, particularly percentage calculations, to identify the levels of validity and practicality, with criteria referring to Tables 1 and 2.

To measure the enhancement of students' mathematical communication abilities, the pretest and posttest results were evaluated using the normalized gain (N-Gain) Formula (1):

$$N - Gain = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score} \quad \ldots (1)$$

The obtained N-Gain scores were subsequently classified according to the following categories (Majdi et al., 2018):

N-Gain > 0.7	: High category
0.3 ≤ N-Gain ≤ 0.7	: Medium category
N-Gain < 0.3	: Low category

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Because this study employed a descriptive design without a control group, no inferential statistical tests (e.g., t-test or Wilcoxon) were performed. The analysis focused solely on describing the category of improvement based on N-Gain scores.

Quantitative data collected from validation forms, mathematical communication skill assessments, and student response questionnaires were processed using descriptive statistical methods to identify the levels of validity, practicality, and enhancement of students' mathematical communication abilities. The improvement in students' performance was determined by comparing the pre-test and post-test scores. Meanwhile, qualitative data consisting of validators' comments, suggestions, and observational results were analyzed descriptively to complement the quantitative findings and provide input for revising and improving the learning media.

Result and Discussions

This study employed the ADDIE model as a framework for developing learning media, which consists of the stages of Analyze, Design, Development, Implementation, and Evaluation. The purpose of this study was to develop interactive ethnomathematics-based learning media using Articulate Storyline 3 that integrates the local culture of Kuningan Regency. The developed learning media is expected to improve students' mathematical communication skills on trigonometric ratio material in Grade X.

Results of the Needs Analysis Stage

The needs analysis stage was undertaken as a preliminary step to identify challenges in mathematics instruction and to examine students' needs concerning the improvement of mathematical communication skills. This process involved direct observation of mathematics learning activities at MAN 1 Kuningan, interviews with mathematics teachers, and an analysis of curriculum documents along with the instructional materials implemented at the school.

Based on the observation results, mathematics learning in Grade X was still dominated by conventional, teacher-centered methods, with learning media limited to textbooks and the whiteboard. This situation led to a low level of student participation during the learning process, particularly in expressing ideas, explaining concepts, and communicating mathematical understanding both orally and in writing. Consequently, students' mathematical communication skills were relatively low, especially in trigonometric ratio material, which requires strong conceptual understanding and mathematical representation.

The results of interviews with mathematics teachers indicated that students tended to experience difficulty in relating trigonometric concepts to real-life contexts. In addition, students were not accustomed to expressing mathematical thinking processes systematically. Teachers also stated that there was no interactive learning media available that could facilitate active student involvement while integrating local cultural contexts that are close to students' daily lives.

Curriculum document analysis showed that trigonometric ratio material in Grade X requires students to understand concepts, use mathematical representations, and communicate problem-solving results. However, the learning tools currently used do not fully support the achievement of these competencies, particularly in terms of mathematical communication skills and the utilization of learning technology.

Furthermore, analysis of the learning environment revealed that most students already have access to technological devices such as laptops or smartphones and are familiar with using digital media in their daily lives. The school also possessed sufficient technological infrastructure to facilitate the implementation of interactive learning media. However, the integration of such technology into mathematics instruction has not yet been maximized.

Based on the results of the needs analysis, it can be concluded that the development of interactive learning media is required not only to support students' understanding of trigonometric ratio concepts but also to enhance their mathematical communication skills. The learning media to be developed should integrate ethnomathematical contexts based on the local culture of Kuningan Regency and utilize interactive technology that is easily accessible to students. These analysis results subsequently serve as the basis for determining the content, design, cultural context, and characteristics of the learning media to be developed in the next stage.

Results of the Design Stage

At the design stage, two main products were produced: a flowchart and a storyboard for the "World of Trigonometry" learning media. Figure 2 presents the storyboard of the "World of Trigonometry" learning media. The storyboard illustrates the visual layout of each page in the learning media, including the placement of text, images, navigation buttons, and interactive elements. The design integrated the local cultural context of Kuningan Regency, such as traditional batik motifs, historical sites (Cipari Archaeological Park, Ikan Dewa Statue, and Lodaya Statue), and Sundanese cultural elements (e.g., characters wearing blangkon and holding wayang).

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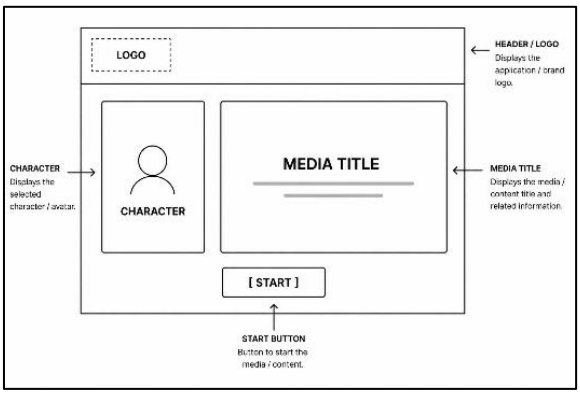

Figure 2. Storyboard of the world of trigonometry learning media

Figure 3 presents the flowchart of the "World of Trigonometry" learning media. The flowchart maps the navigation structure of the learning media, consisting of several main pages: start page, login page, main menu, learning objectives, prerequisite materials, core materials, local culture introduction, quiz, developer profile, and bibliography. Both the flowchart and storyboard served as the blueprint for developing the interactive learning media using Articulate Storyline 3 in the subsequent development stage.

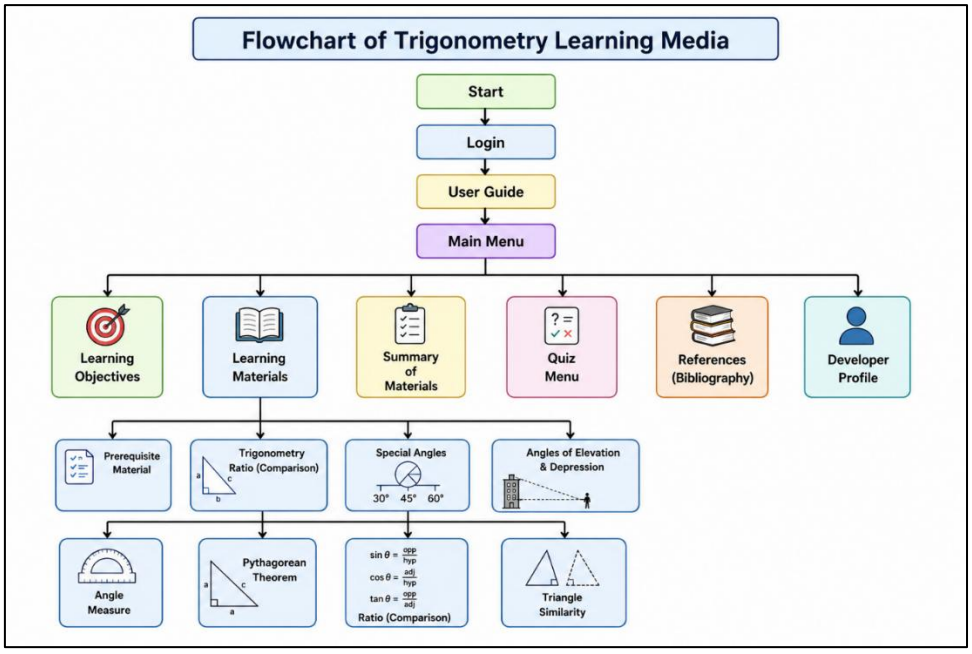

Figure 3. Flowchart of the world of trigonometry learning media

Results of the Development Stage

The development stage focused on the process of creating learning media using Articulate Storyline 3. The learning materials were designed by integrating various interactive components, such as videos, quizzes, text, and elements of local culture,

with the aim of increasing student engagement and participation in the learning process. Prior to the development process, the researchers first prepared a flowchart and storyboard as guidelines for designing the interactive learning media. Subsequently, the media development was carried out using the Articulate Storyline 3 application, which involved two main activities: the development of interactive learning media and the arrangement of media accessibility to ensure that it can be used optimally by students (Figure 4).

Figure 4. Sample results of developing the world of trigonometry learning media

After the development process of the learning media was completed, the researchers ensured that the Articulate Storyline 3–based media could be accessed by users by downloading and installing it. At this stage, the learning media were converted into an application compatible with mobile devices, such as smartphones and tablets, so that they could run properly. This learning application was provided through a specific platform to allow students to access it easily without time and place limitations.

Before being implemented with students, the developed media underwent a validity test. The validity of the "Trigonometry World" learning media is one of the main aspects determining its quality and feasibility for use in the learning process. The validity assessment was conducted through several stages involving subject-matter experts and media experts who have competence in their respective fields. The experts evaluated the learning media based on various aspects, including the suitability of the material with the applicable curriculum, the accuracy and appropriateness of the learning content, as well as the quality of visual design and the level of interactivity presented in the media.

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The questionnaire instrument used to assess the validity of this interactive learning media was distributed to two groups of experts, namely lecturers in Mathematics Education from the Faculty of Teacher Training and Education (FKIP), Universitas Kuningan, and mathematics teachers at MAN 1 Kuningan. The validity assessment process was carried out by four material experts: NN, RS., SSA, and TUM. Based on the experts' evaluations, the developed interactive learning media obtained a validity percentage of 93.21%, which falls into the very valid category. This result indicates that the media have met the feasibility criteria in terms of content quality and language use, and therefore are considered appropriate for use in the learning process.

In the evaluation process of the Trigonometry World learning media, two main aspects were assessed in depth, namely content feasibility and language aspects. The assessment of these two aspects was conducted by material expert validators. A summary of the evaluation results from the material experts is subsequently presented in the form of a material expert validation table and a recapitulation table of the evaluation results based on each assessed aspect.

Table 3. Recapitulation of material expert validators

No	Validator	Score (Max Score 280)
1	NN	65
2	RS	61
3	SSA	66
4	TUM	69
	Total Score	261
	Score Percentage (%)	93.21
	Validity Category	Very Valid

Based on the calculation of validity percentages from the material experts, the interactive learning media obtained a validity score of 93.21%, which falls into the very valid category (Table 3). However, a validity percentage alone does not explain why the media is considered valid. Therefore, a deeper analysis of the two assessed aspects (Table 4) reveals that the content feasibility aspect achieved a higher percentage (94.37%) compared to the language aspect (91.66%). This indicates that the strongest aspect of the media is the alignment of the material with learning objectives and curriculum, while the language aspect, though still very valid, requires minor improvements in notation consistency and instructional dialogue. Furthermore, compared with previous studies using similar interactive media, the validity score of 93.21% is higher than that reported by Pradnyani & Paramita (2024) at 86.5% and Mufidah & Khoiri (2021) at 84.2%, suggesting that the integration of ethnomathematics

may enhance content validity by providing contextual relevance that pure interactive media lack.

Table 4. Recapitulation of percentage per aspect of material experts

No	Aspect	Score (%)
1	Content Feasibility	94.37
2	Language	91.66

The revisions provided by the material experts to the Trigonometry World interactive learning media included several important improvements aimed at enhancing the quality of the content and the accuracy of its presentation. Several writing errors in the developer profile section were corrected to ensure that the information presented became clearer and more accurate. In addition, the integration of local cultural wisdom from Kuningan Regency in the form of case studies was enriched to strengthen cultural relevance and to bring the learning material closer to students' real-life experiences.

Improvements were also made to the substantive aspects of the material, particularly in the discussion of square root results within the concept of the Pythagorean theorem, to ensure the accuracy of the mathematical concepts presented. Images illustrating angle measurements were supplemented with rotational direction indicators to help students understand angle concepts more clearly and systematically.

From the perspective of instructional planning, the sequence of learning objectives was reorganized in accordance with the ABCD theory (Audience, Behavior, Condition, Degree) so that the learning objectives became more structured and measurable. The characters used in the learning media were also updated by incorporating elements of local culture, making the media display more contextual and engaging for students.

Furthermore, previously inaccurate degree notation was corrected to produce a clearer and more consistent presentation. Adjustments were also made to the notation of time and the notation of AB in the prerequisite materials to ensure compliance with correct mathematical conventions. Overall, these revisions indicate that the Trigonometry World learning media has undergone improvements in quality in terms of content, language, and visual aspects, making it increasingly suitable for use as a mathematics learning medium in schools.

The media expert validity questionnaire was administered to the Head of the Division of Innovation, Publication, and Intellectual Property Rights at the Institute for Research and Community Service (LPPM), Universitas Kuningan, as well as to a teacher from MAN 1 Kuningan to evaluate the developed interactive learning media.

The media validity assessment was conducted by two media experts, namely ED and TN. Based on the calculation of the validity percentages from both media experts, the interactive learning media obtained a validity score of 96.92%, which falls into the very valid category.

Table 5. Media expert validator recapitulation

No	Validator	Score (Max Score 130)
1	ED	57
2	TN	64
	Total Score	126
	Score Percentage (%)	96.92
	Validity Category	Very Valid

Validation by media experts is a crucial stage in the development process of learning media because it aims to ensure the quality of the media from various technical and visual perspectives. The media expert assessment covered three main aspects, namely presentation, visual appearance, and media suitability or compatibility. The results of the media experts' evaluations are subsequently presented in the form of a media expert validator recapitulation table (Table 5) and a recapitulation table of evaluation results based on each assessed aspect (Table 6).

Table 6. Recapitulation of percentage per aspect of media experts

No	Aspect	Pecentage Score (%)
1	Presentation	100
2	Appearance	80
3	Compatibility	94

The revisions provided by the media experts to the Trigonometry World interactive learning media included several important improvements aimed at enhancing the quality and consistency of the media. Inconsistencies in the use of symbols and the navigation system were identified and subsequently corrected so that the media display became more uniform and easier to use. In addition, all navigation buttons in the media were relocated to the user guide section, enabling users to understand the function of each button and the navigation flow more clearly. These revisions are expected to improve the effectiveness of use as well as user comfort in utilizing the interactive learning media.

Besides undergoing validity assessment, the Trigonometry World learning media were also examined for practicality through direct application in classroom instruction. The practicality evaluation involved both teachers and students in authentic learning settings, where the media were implemented during the teaching

and learning activities. This process provided a more objective understanding of the users' acceptance of the media as well as its ease of use for both students and teachers.

According to the calculation of practicality percentages based on students' responses, the Trigonometry World media achieved a score of 92.85% (Table 7), which is categorized as very practical.

Table 7. Recapitulation of student practicality questionnaire

No	Validator	Score (Max Score 560)
1	ANF	60
2	MAA	65
3	MHH	65
4	NFA	70
5	DNF	67
6	RJA	69
7	KSW	68
8	MFF	56
	Total Score	520
	Score Percentage (%)	92.85
	Practicality Category	Very Practical

The evaluation from the students' perspective covered three primary dimensions: usefulness, ease of operation, and user satisfaction (Table 8). These findings suggest that the developed learning media are highly effective in supporting the teaching and learning process, easy to use, and able to provide an enjoyable learning experience for students.

Table 8. Recapitulation of percentage per aspect of student practicality

No	Aspect	Score (%)
1	Usefulness	94.50
2	Ease	90.00
3	Satisfaction	94.37

Apart from student evaluations, the practicality of the learning media was also assessed from the teachers' viewpoint. Based on the teachers' practicality percentage calculations, the developed interactive learning media achieved a score of 96.66% (Table 9), which is classified as very practical. These findings demonstrate that the media are regarded as user-friendly, relevant to instructional requirements, and effective in facilitating classroom teaching and learning activities (Table 10).

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Table 9. Recapitulation of teacher practicality questionnaire

No	Validator	Score (Max Score 120)
1	SSA	58
2	TUM	58
	Total Score	116
	Score Percentage (%)	96.66
	Practicality Category	Very Practical

Table 10. Recapitulation of percentages per aspect of teacher practicality questionnaire

No	Aspect	Score (%)
1	Effective	100
2	Interactive	97.50
3	Efficient	90
4	Creative	95

Results of the Implementation Stage

The implementation stage was conducted from May 30 to June 2, 2024, involving 23 tenth-grade students of MAN 1 Kuningan (Class XA) over three meetings, each lasting 90 minutes. Based on classroom observations during the implementation, several findings were recorded. First, students actively engaged with the interactive features of the "World of Trigonometry" media, particularly the quiz section and the local cultural content (batik motifs, historical sites of Kuningan Regency). Second, students demonstrated increased participation in asking and answering questions compared to previous conventional lessons. Third, some technical issues were observed: two students experienced delays (lag) when accessing the media on smartphones with Android version below 5.0.

The student response questionnaires, administered after the implementation, yielded the following specific findings: 92.85% of students found the media practical (as reported in the practicality section), with 94.50% of students agreeing that the media was beneficial, 90.00% agreeing that it was easy to use, and 94.37% expressing satisfaction with the learning experience. These quantitative findings are detailed further in the evaluation stage. Observational data also revealed that students who initially had low pretest scores (below 30) showed increased confidence in explaining trigonometric concepts during the final meeting, although structured written communication skills required further reinforcement.

Results of the Evaluation Stage

The evaluation stage measured the improvement in students' mathematical communication skills by comparing pretest and posttest scores. The average pretest score was 12 (on a 30-point scale), which increased to 16.39 in the posttest. Based on

the N-Gain analysis, the average N-Gain score was 0.55 (medium category), indicating a moderate improvement after using the "World of Trigonometry" learning media.

The N-Gain distribution among the 23 students was as follows: 6 students (26%) showed low improvement (N-Gain < 0.3), 7 students (30%) showed medium improvement (0.3 ≤ N-Gain ≤ 0.7), and 10 students (44%) showed high improvement (N-Gain > 0.7). The variation in improvement categories suggests that the effectiveness of the media varies depending on students' prior knowledge and learning styles.

Several factors explain why the overall improvement did not reach the high category (>0.7). First, based on analysis of student answer sheets, the lowest improvement was observed in the indicator of explaining mathematical concepts using one's own language (N-Gain = 0.50) and conveying mathematical contexts (N-Gain = 0.52). Many students still struggled to write what was known and asked in the problem before beginning to solve it (Dila & Zanthy, 2020; Latifah & Afriansyah, 2021; Wau et al., 2022). Second, some students were unable to draw appropriate conclusions from their problem-solving processes. Third, computational errors occurred frequently, particularly in applying trigonometric formulas to contextual problems.

Furthermore, students' mathematical communication skills are influenced by various factors, including students' interest in learning mathematics, mastery of basic mathematical knowledge, conceptual understanding of the material being studied, students' activeness during the learning process, and the role of teachers in facilitating and guiding students' learning processes (Nuraini et al., 2020; Wau et al., 2022; Lubis & Rahayu, 2023; Suhenda & Munandar, 2023).

It is important to note that this study used a descriptive design without inferential statistical tests (e.g., t-test or Wilcoxon) because the aim was to describe the category of improvement (low, medium, high) rather than to generalize findings to a population. No control group was involved, and the sample was selected purposively. Therefore, the N-Gain results are interpreted descriptively. Although the improvement is still in the medium category, the use of ethnomathematics-based interactive learning media has shown a positive impact. Further efforts are needed to optimize the influencing factors so that improvements in students' mathematical communication skills can reach a higher category in future studies.

Based on the analysis presented in Table 11, the findings of this study indicate that the use of the "World of Trigonometry" learning media based on ethnomathematics and Articulate Storyline 3 improved students' mathematical communication skills with an N-Gain of 0.55 (medium category). This result is consistent with previous studies by

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Rizal et al. (2021), who reported an N-Gain of 0.51 in the medium category for ethnomathematics-based e-modules. The similarity in results suggests that the integration of ethnomathematics into interactive digital media reliably produces medium-category improvements in mathematical communication skills.

Table 11. N-Gain Results Per Communication Ability Indicator

Indicator Mathematical Communication Ability	Pre-test Score	Post-Test Score	N-gain	Criteria
The ability to convey mathematical context involves various means, such as the use of language, symbols, ideas, or mathematical models, including pictures, diagrams or real objects.	10.48	15.39	0.52	Medium
The ability to explain mathematical concepts, situations, and relationships using one's own language, in writing	9.09	16.57	0.50	Medium
The ability to explain the results of mathematical calculations in writing	16.43	19.22	0.78	High
Overall average	12	16.39	0.55	Medium

The findings of this study also provide empirical support for the theoretical frameworks proposed by Cuevas (1991) and Habala & Demlova (2019). Cuevas (1991) asserted that effective mathematical communication instruction must embed opportunities for students to use language, symbols, and representations in meaningful contexts rather than isolated drills. The "World of Trigonometry" media operationalized this principle by embedding trigonometric problems within Kuningan's cultural artifacts (e.g., traditional batik motifs, historical sites), requiring students to explain concepts using both mathematical notation and contextual descriptions. Furthermore, Habala & Demlova (2019) argued that comprehension of mathematical language involves mastering its discrete components (symbols, syntax, and logical structure) before integrating them into holistic reasoning. The medium N-Gain of 0.55 in this study suggests that while students improved, the three-meeting implementation period (90 minutes each) may have been insufficient for full mastery of the "discrete approach" to mathematical language comprehension, particularly for the 26% of students who showed low improvement. This aligns with Habala & Demlova's (2019) caution that mathematical language acquisition is non-linear and requires sustained exposure.

More recent large-scale studies reinforce these interpretations. Aljura et al. (2025) conducted a comprehensive analysis involving 1.036 eighth-grade students and found that mathematical reasoning and communication are distinct but correlated skills, with word problems serving as an effective bridge between the two. Their structural

equation modeling revealed that students who practiced integrated reasoning-communication tasks showed 34% better performance on transfer problems compared to those practicing isolated skills. The present study's finding that procedural communication (explaining calculation results, N-Gain = 0.78, high category) improved more than conceptual communication (explaining concepts in one's own words, N-Gain = 0.50) is consistent with Aljura et al. (2025) observation that reasoning skills often develop alongside procedural communication before fully transferring to explanatory communication. Similarly, Riyanto (2025) demonstrated through classroom action research that implementing Realistic Mathematics Education (RME) principles—which share substantial overlap with ethnomathematics in their emphasis on contextualization—resulted in a 32% increase in students' ability to articulate mathematical reasoning verbally over four cycles. Riyanto (2025) specifically noted that "bridging mathematics and communication" requires iterative cycles of contextual problem-solving followed by structured reflection, a design feature that could strengthen future iterations of the "World of Trigonometry" media, particularly for indicators that showed only medium improvement.

These findings align with international research from various cultural contexts. Ndagijimana et al. (2024) found that students using GeoGebra within a socio-cultural learning context significantly outperformed those in traditional instruction ($p < 0.001$), demonstrating that technology integration with cultural relevance enhances mathematical understanding . Their study involved 279 first-year secondary students in Rwanda, providing evidence from an African educational context. Similarly, Nugroho et al. (2025) reported that ethnomathematics-based digital books achieved significant improvements, with post-test scores rising from 60 to 78.6 (an increase of 18.6 points) and 74% of students achieving learning completion. The consistency of these findings across Indonesia, Rwanda, and Southeast Asian countries suggests that ethnomathematics-based digital media have cross-cultural applicability.

Among the three indicators assessed, the highest improvement was observed in the ability to explain mathematical calculation results in written form (N-Gain = 0.78, high category). This finding can be explained by the design of the learning media, which provided structured step-by-step examples, quizzes with immediate feedback, and visual representations of trigonometric calculations. This finding is consistent with the results of Sari and Qohar (2023), who developed Articulate Storyline 3 media for cube material and reported that students' positive responses reached 93.35%, indicating that the interactive features of Articulate Storyline 3 effectively facilitate procedural understanding. Lail et al. (2024) similarly reported that Articulate Storyline 3 media for 3D shapes achieved material expert validation of 90% and media expert validation of 87%, both categorized as "Very Satisfied," with the interactive features enabling

students to directly engage with the material. The high N-Gain in this indicator also aligns with Sari et al. (2025), who found that Articulate Storyline 3 media effectively improved students' critical thinking through structured, interactive tasks that mirror the step-by-step procedural learning demonstrated in the present study.

In contrast, the lower improvements in conveying mathematical contexts (N-Gain = 0.52) and explaining concepts using one's own language (N-Gain = 0.50) suggest that these skills require more time and practice to develop. Rodríguez-Nieto et al. (2023) noted that while interactive ethnomathematics tasks effectively develop reasoning and justification skills, the development of more complex communicative competencies such as "criticizing the conclusions presented by others" requires more sophisticated task design and extended implementation time . Their study, published in the Journal on Mathematics Education, emphasized that conceptual communication skills emerge gradually and require sustained exposure to dialogic learning environments. The media may have been more effective in facilitating procedural communication than conceptual communication because the quiz questions primarily focused on calculation-based tasks. Future development should include more open-ended questions that require students to explain concepts verbally.

The medium overall improvement (0.55) also reflects the influence of external factors beyond the media itself. As noted by Wau et al. (2022), students' interest in mathematics, prior knowledge, and teacher facilitation play crucial roles in determining learning outcomes. In this study, 6 out of 23 students (26%) showed low improvement (N-Gain < 0.3), which may be attributed to low initial motivation or limited mastery of prerequisite concepts such as the Pythagorean theorem and basic angle measurement.

Compared to studies using conventional learning media without ethnomathematics integration, such as Pradyani & Paramita (2024) who reported an N-Gain of 0.42, the present study's N-Gain of 0.55 is higher. This suggests that the integration of local cultural contexts (Kuningan Regency) may enhance students' engagement and meaningful learning, supporting the theoretical claim that ethnomathematics makes mathematics more accessible and relevant to students' daily lives (Khaerani et al., 2024; Siregar et al., 2024).

In conclusion, the "World of Trigonometry" learning media is effective in improving students' mathematical communication skills, particularly in written calculation explanations. However, to achieve high-category improvements across all indicators, future research should (1) extend the duration of media use, (2) incorporate more activities requiring verbal and written concept explanations, and (3) address technical

issues such as device compatibility to ensure all students can access the media without delay.

Conclusion

This study successfully developed an interactive learning media, "Dunia Trigonometri," based on Articulate Storyline 3 with an ethnomathematics approach to enhance students' mathematical communication skills. The media were found to be highly valid (93.21% from material experts, 96.92% from media experts) and highly practical (92.85% from students, 96.66% from teachers), with an N-Gain of 0.55 (medium category) indicating a positive impact on students' mathematical communication skills, particularly in explaining calculation results in written form (N-Gain = 0.78, high category).

The scientific contribution of this study are threefold. First, it provides empirical evidence that the systematic integration of local cultural contexts into interactive Articulate Storyline 3 media is not only feasible but also effective. Second, it offers a validated development model (ADDIE) for ethnomathematics-based digital media that can be adapted to other local cultures. Third, it demonstrates that interactive media can enhance students' mathematical communication skills, especially procedural communication (explaining calculation results), though conceptual communication (explaining concepts in one's own words) requires further reinforcement.

The theoretical implication of this study supports the view that ethnomathematics makes mathematics more accessible and relevant to students' daily lives. It also suggests that visual and interactive presentations help reduce students' cognitive load and improve their ability to articulate calculation procedures. Practically, these media can be used by mathematics teachers as an innovative alternative for teaching trigonometry at the senior high school level, particularly in regions with rich local cultural heritage. The media's offline accessibility and mobile compatibility make it suitable for schools with limited internet infrastructure.

This study has several limitations that should be acknowledged. First, the media was tested with only 23 students from one school, which limits the generalizability of the findings. Second, the study used a one-group pretest-posttest descriptive design without a control group, so the improvement cannot be definitively attributed solely to the media. Third, the material was limited to trigonometric ratios; the media has not been tested for other topics. Fourth, some students experienced technical delays on smartphones with older Android versions.

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For future research, it is recommended to: (1) conduct quasi-experimental studies with a control group to establish causality, (2) expand the material coverage to other trigonometry topics, (3) optimize the media's technical compatibility across a wider range of devices, and (4) investigate the development of other mathematical skills using the same ethnomathematics-based interactive approach.

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