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Digital Trigonometry Module Utilizing LiveWorksheet to Enhance University Students' Mathematical Communication Skills

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Abstract: *Supporting the development of university students' cognitive skills in higher education necessitates the design of instructional materials that cultivate critical thinking. Integrating technology into teaching resources has become prevalent in higher education, proving effective in advancing students' skills. This study aims to evaluate the validity of a digital trigonometry module based on LiveWorksheet, assess its practicality from the users' perspective, and determine its effectiveness in enhancing mathematical communication skills. The study follows a research and development with five phases: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. Participants included two experts-one in mathematics education and another in ICT education and 62 students (Class A, n=32; Class B, n=30). These students were enrolled in a trigonometry course taught by the researcher. Data were gathered via questionnaires and mathematical communication skill assessments, with qualitative descriptive analysis used to address the research objectives. Results indicate that the digital trigonometry module meets established validity criteria. The implementation findings demonstrate that the module is both practical for users and effective in enhancing students' mathematical communication skills, with average student performance reaching a high level. These findings suggest that LiveWorksheet-based digital instructional materials, particularly when incorporating media such as videos and interactive quizzes, can significantly enrich learning support.*

Keywords: Digital trigonometry module; LiveWorksheet; mathematical communication skills; *research and development*

Modul Digital Trigonometri Berbasis Liveworksheet dalam Menunjang Kemampuan Komunikasi Matematis Mahasiswa Perguruan Tinggi

Abstrak: Dalam menunjang keterampilan mahasiswa pada permbelajaran di perguruan tinggi perlu didesain bahan ajar yang dapat menunjang keterampilan berpikir mahasiswa. Pemanfaatan teknologi dalam bahan ajar menjadi trend yang dilakukan diperguruan tinggi dan telah terbukti efektif untuk mengembangkan keterampilan mahasiswa. Penelitian ini bertujuan untuk mendeskripsikan validitas modul digital trigonometri berbasis liveworksheet, mengevaluasi kepraktisan dari pengguna, dan efekivitas ditinjau dari kemampuan komunikasi matematis. Penelitian ini menggunakan penelitian dan pengembangan (research and development) dengan lima tahapan pelaksanaan yaitu: (1) analysis, (2) design, (3) develop, (4) implementation, dan (5) evaluation. Dalam penelitian ini melibatkan dua orang expert (dosen A, bidang pendidikan matematika; dosen B; bidang pendidikan TIK) dan 62 orang mahasiswa (Kelas A, n=32; kelas B, n=30). Subjek dipilih adalah mahasiswa yang menandatangani kontrak perkuliahan trigonometri dengan peneliti sebagai dosen pengampu. Data dikumpulkan melalui instrument angket dan tes kemampuan komunikasi matematis. Analisis data penelitian dilakukan secara deskriptif kualitatif dalam menjawab fokus penelitian. Hasil penelitian menunjukkan bahwa modul digital trigonometri memenuhi kriteria valid. Hasil implementasi modul menunujukkan bahwa modul memenuhi kriteria

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praktis oleh pengguna dan efektif dalam menunjang kemampuan komunikasi matematis mahasiswa dengan rata-rata capaian pada kriteria tinggi. Berdasarkan temuan penelitian ini penggunaan bahan ajar digital berbasis liveworkheet dapat memaksimalkan media bantu seperti video, kuis interaktif yang disediakan pada fitur dari aplikasi.

Kata Kunci: Modul digital Trigonometri; liveworksheet; kemampuan komunikasi matematis; penelitian dan pengembangan

INTRODUCTION

Communication skills are among the critical competencies required for 21st-century learning (Soulé & Warrick, 2015), and they are especially vital in higher education. University curricula are increasingly aligned with the demands of Industry 4.0, emphasizing the need for graduates to possess strong data and technology literacy skills (Junaidi, 2020). To support the development of these skills, it is essential to design learning resources that actively foster and strengthen such competencies. However, a primary challenge in higher education is the limited availability of learning resources that effectively support students' skill development (Susanto et al., 2021). This limitation highlights the need for a comprehensive examination of instructional materials that can promote students' higher-order thinking skills.

A survey conducted among 20 mathematics education students in the Faculty of Teacher Training and Education during the 2024/2025 academic year revealed that 14 students (70%) encountered difficulties in understanding course material as presented by instructors. This issue stems in part from students' limited familiarity with accessing supplementary resources to enhance their understanding of assigned topics. Further, empirical data from the final exam in the 2023/2024 academic year's odd semester show that the average score of 30 students in a trigonometry course was 63.25 (on a scale of 0–100), indicating that learning outcomes in this course require substantial improvement.

The integration of technology into instructional design offers a promising approach to addressing these challenges. Such innovation aligns with the increasing demand for graduates proficient in technology use. Recent research underscores the significant role of technology in enhancing learning outcomes (Susanto et al., 2024). Digital media and technology not only accelerate knowledge acquisition Wijaya et al. (2016) but also foster skill development through innovative learning approaches (Susanta, Koto, et al., 2022). Furthermore, online instructional materials facilitate easy access to information and serve as effective motivational tools for learners (Kefalis & Drigas, 2021).

The COVID-19 pandemic has also underscored the value of online learning as a necessary complement to traditional classroom instruction. The availability of technology has made online learning resources essential tools for students, enabling them to engage with course content independently and flexibly. This shift emphasizes the dual importance of developing both 21st-century skills and virtual learning competencies (Puncreobutr, 2016). Digital modules, in particular, make instructional materials more engaging and adaptable (Fonda & Sumargiyani, 2018), support contextualized learning, organize learning processes, enrich content, and foster positive attitudes towards learning (Harianto et al., 2017).

Prior studies indicate that digital modules can significantly enhance learning outcomes. For example, Susanto & Susanta (2022) found that interactive modules effectively improved students' literacy skills. Digital modules have also been shown to promote critical thinking (Jayadiningrat & Ati, 2018; Rizal et al., 2024) , improve academic performance (Mutmainnah & Warneri, 2021), develop higher-order thinking skills (HOTS) (Indiyanti et al., 2023; Tobing et al., 2021), and enhance mathematical literacy (Susanta, Sumardi, et al., 2022).

LiveWorksheet is one platform that supports digital learning by enabling the design of interactive learning activities (Yuniastuti & Khoiron, 2021). The availability of digital instructional resources is crucial for curriculum support, providing students with structured, self-directed learning opportunities. This study, therefore, aims to develop a LiveWorksheet-based digital trigonometry module to enhance university students' mathematical communication skills.

METHOD

Research Design

This study employs a research and development framework to produce an educational product (Plomp & Nieveen, 2013), specifically a LiveWorksheet-based digital trigonometry module. The primary objectives are to ensure that the module is valid and practical and to assess its effectiveness in enhancing students' mathematical communication skills within a trigonometry course.

The module development process follows the ADDIE model, which comprises the stages of Analysis, Design, Development, Implementation, and Evaluation. This model aligns with the study's objectives, supporting the systematic production of an instructional module that meets criteria for validity, practicality, and potential impact. The process begins with a needs analysis to identify instructional requirements, followed by designing the module to address these needs. The development phase involves expert assessments, and classroom implementation subsequently evaluates the module's practicality and effectiveness.

Subjects

The study's trial phase involved two experts and 62 students from the mathematics education program at Bengkulu University. The experts were responsible for evaluating the content, structure, and language of the digital trigonometry module. The first expert (Lecturer A) specializes in mathematics education at Bengkulu University, while the second expert (Lecturer B) specializes in ICT education at Dehasen University, Bengkulu. During the implementation phase, participants included students from two mathematics education classes (Class A, n=32; Class B, n=30). At the time of the study, all participating students were enrolled in a trigonometry course, with both classes taught by the same instructor using the LiveWorksheet-based digital module.

Data Collection and Instruments

Data were collected through questionnaires and tests. The questionnaires assessed the module's validity and practicality, while the tests measured the module's effectiveness in enhancing learning outcomes. The questionnaire used a four-point Likert scale, with responses ranging from 1 (very poor) to 4 (excellent). The expert assessment instrument

included 12 items addressing content presentation (n=3), interactive video quality (n=3), LiveWorksheet integration (n=3), and project design (n=3). The practicality evaluation comprised 10 items focusing on the module's visual appeal (n=3), video accessibility (n=2), LiveWorksheet accessibility (n=3), and learning process quality (n=2).

The test instrument was designed to assess mathematical communication skills through written response questions. Based on the NCTM (2000) guidelines, the test evaluated three indicators of mathematical communication: expressing ideas in writing, interpreting visuals, and using mathematical expressions. To measure these skills, the study employed a scoring rubric.

Table 1. Scoring for Mathematical Communication

Indicator	Criteria	Score
Expression of Ideas	1. The student accurately and thoroughly records information from the problem	3
	2. The student accurately records information but with minor omissions	2
	3. The student records information inaccurately	1
	4. No response provided	0
Visual Interpretation	1. The student provides a complete and accurate visualization of the problem using diagrams or tables	3
	2. The student provides a generally accurate visualization with minor omissions	2
	3. The student provides an inaccurate visualization	1
	4. No response provided	0
Mathematical Expression	1. The student accurately models the problem mathematically and performs complete and correct calculation	3
	2. The student correctly models the problem but with partial calculations	2
	3. The student's mathematical model or calculations are incorrect	1
	4. No response provided	0

The mathematical communication test instrument developed for this study focuses on the application of trigonometric concepts, specifically angles of elevation and depression. The instrument underwent content validation by two experts specializing in mathematics education. Descriptive analysis confirmed that the instrument meets validity standards, affirming its suitability for evaluating the effectiveness of the digital module.

Data Analysis

The data analysis in this study is aligned with the primary objectives, which are to evaluate the validity, practicality, and effectiveness of a LiveWorksheet-based digital trigonometry module in enhancing learning outcomes. To achieve these objectives, a qualitative descriptive analysis approach was employed.

Initially, the validity analysis was conducted based on evaluations from two experts (Lecturer A and Lecturer B). Expert assessments were analyzed using inter-rater agreement, employing the Kappa test (Landis & Koch, 1977), with a Kappa value greater than 0.5

considered acceptable. The validity analysis also incorporated expert feedback and suggestions, which were subsequently used to refine the product.

Practicality was analyzed descriptively, based on student responses to a questionnaire administered after using the module. The average score for each item was categorized into five levels: very practical, practical, sufficient, less practical, and not practical. The score intervals were based on a 1-5 scale, as outlined in Table 2.

Table 2. Practicality Analysis Guidelines

Score Range	Category
4.21-5.00	Very Practical
3.41-4.20	Practical
2.61-3.40	Sufficient
1.81-2.60	Less Practical
1.00-1.80	Not Practical

The practicality of the digital teaching module was assessed based on the average scores from student evaluations. If the average score fell within the "practical" or "very practical" categories, the module was considered practical.

Effectiveness was assessed based on students' performance in a mathematical communication test, which included three test questions. Student responses were scored on a scale from 0 to 100. The students' mathematical communication skills were then classified into three categories: low (score ≤ 33), moderate (33 < average ≤ 66), and high (> 67). The product was considered effective if the average score of students fell within the "high" category. Additionally, the effectiveness criterion was met if more than 50% of students achieved a moderate to high skill level.

RESULTS AND DISCUSSION

Analysis Results

The analysis conducted aimed to identify the initial requirements for the development of the research product (needs analysis). This analysis specifically focused on the learning outcomes to be achieved and the selection of appropriate digital media for delivering the content. In this development research, the needs of students and instructors were not considered in the analysis, as the researcher also served as the course instructor. The focus of the study was to explain the concepts of angles of elevation and depression, as well as to solve real-world problems. These topics were selected due to students' previously limited ability to apply trigonometry to real-world problems in prior courses.

The initial analysis led to the design of the platform for the digital module. The platform chosen, based on the analysis, was LiveWorksheet. This platform was selected because it allows students to learn both with guidance and independently. LiveWorksheet enables students to complete assignments and submit them directly to the instructor via email, facilitating efficient evaluation. Additionally, LiveWorksheet can integrate learning resources

such as instructional videos and interactive quizzes, making it an ideal platform for student engagement. It also supports the design of independent project activities, where students can submit their reports through the provided worksheets.

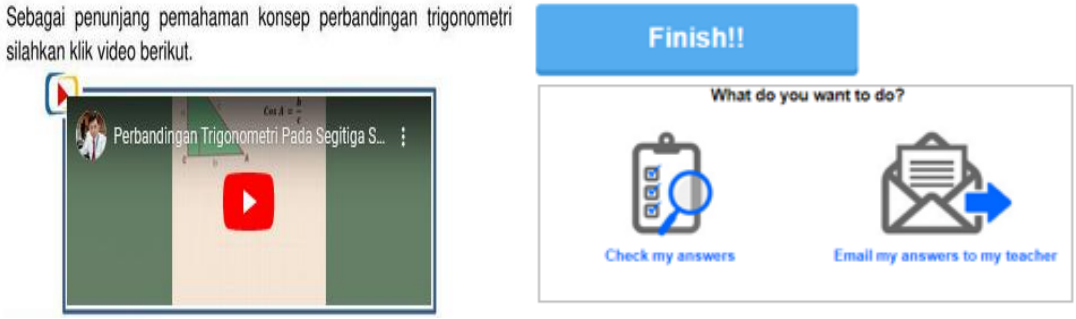


Figure 1. Example of Video Display and Link to Instructor's Email

The image above demonstrates the advantage of LiveWorksheet, which integrates instructional videos that are directly accessible. Users can also provide immediate feedback on the worksheet. This feature is vital for supporting digital learning materials that enable direct responses from users. Another benefit of LiveWorksheet is its capacity to define where completed work should be submitted, which is important for the scalability of instructional materials across various learners.

Design Results

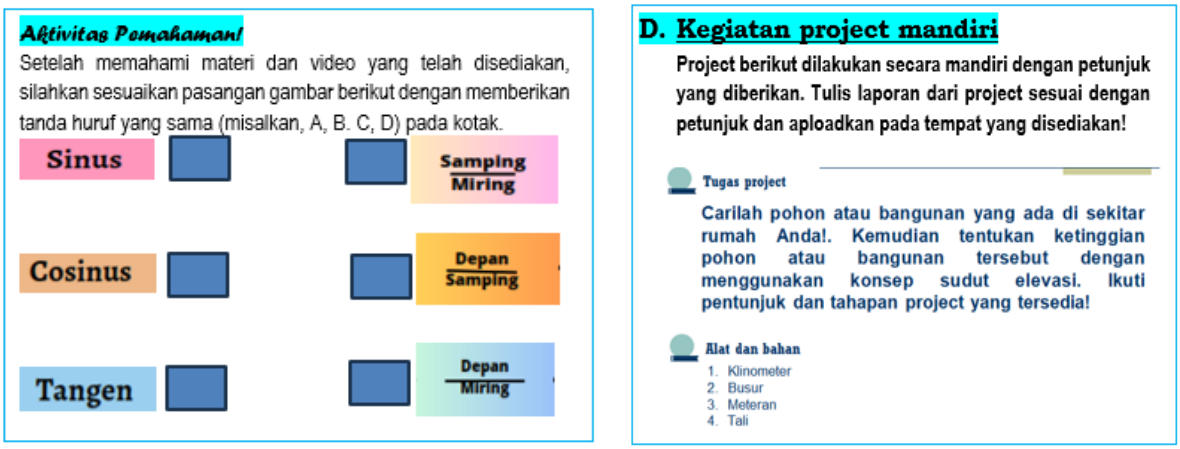
Based on the needs analysis, a digital trigonometry module based on LiveWorksheet was designed. The focus of the design in this study is the application of angles of elevation and depression. This section outlines the characteristics of the digital module resulting from the design phase, rather than describing the development process. The key features of the developed module are as follows.

1. The module is digitally designed using LiveWorksheet as an online platform.
2. The module is systematically organized and includes: a) product description, b) learning outcomes, c) material introduction, d) content presentation, e) independent project activities, and f) reinforcement exercises.
3. The module integrates video content from YouTube.
4. The module also incorporates independent project activities to reinforce the learning material.

Below are several design examples of the LiveWorksheet-based digital trigonometry module

Figure 2. Design of the Digital Trigonometry Module

In addition to the content presentation, which is contextualized with real-world applications and linked to YouTube, the videos containing the instructional material can be directly accessed by users. Another key feature of this digital module is the incorporation of learning activities and independent student projects. These learning activities are designed to actively engage students with the material (Figure 3), while the independent projects further enhance the learning experience. The reports generated from these activities can be evaluated to measure the achievement of the learning objectives. Below, we present examples of the learning activities and independent student projects as shown in Figure 3.



(a) (b)

Figure 3. Module Design (a) Learning Activity, (b) Independent Project

Development Results

The results of this phase include the analysis of data from expert evaluations to assess the validity of the module. To evaluate the validity of the product in this study, two experts specialized in mathematics education and ICT-were consulted. Although the experts came from different fields, they both assessed the same aspects of the digital module. To determine the validity of the expert evaluations, both quantitative and qualitative analyses were performed. In this study, the quantitative analysis employed the Kappa test to assess the inter-

rater agreement between the two experts regarding the developed module. The Kappa test results based on the experts' evaluation scores are presented below.

Table 3. Kappa Test Results

Test	Value	Significance
Measure of Agreement (Kappa)	0.654	0.00
N of Valid Cases	12	

Based on the Kappa test results, it was concluded that there is significant agreement between the experts regarding the assessment of the module. The significance value (0.00 < 0.05) indicates a meaningful level of agreement, with a Kappa value of 0.654, which is considered substantial. Therefore, it can be logically concluded that the developed module meets the validity criteria.

This study emphasizes that the validity of the developed instructional material is not solely based on the calculation of expert evaluation scores but also on the process of integrating expert feedback for improvement. This aspect is critical because, in instructional material development, the process of receiving and implementing expert suggestions plays a pivotal role in ensuring the feasibility and quality of the educational product. A summary of the suggestions provided by the three validators is presented in the table below.

Table 4. Expert Suggestions for Instructional Material

Expert	Suggestions
Validator 1 (Lecturer A)	▪ To enhance student comprehension, it is recommended to include geometric illustrations that facilitate visualization and connection with the material. ▪ Activities for students to practice calculations or understand trigonometric concepts should be provided. ▪ Since students may lack the ability to measure directly, it would be beneficial to include boxes in the trigonometric comparison diagrams, allowing students to write details such as dimensions, angle points, and other relevant information.
Validator 2 (Lecturer B)	▪ As the module is digital, it is recommended to incorporate illustrations in the form of videos or animations, rather than static images. ▪ Supportive instructional videos should be directly accessible through clickable links, preferably connected to YouTube.

The expert suggestions were used to refine the digital trigonometry module in this study. The revision process involved close collaboration with the experts and was carried out through focus group discussions (FGD). The primary focus of the revisions was on improving the content presentation and the digital format. Below, we present examples of the module design before (Figure a) and after (Figure b) the revisions, as shown in Figure 4.

(a) (b)

Figure 4. Module Design (a) Before Revision, (b) After Revision

The figure above demonstrates one of the key improvements, which involved replacing static images with video content. This change was implemented because the digital platform specifically LiveWorksheet offers a more effective means of presenting visual content through videos. Consequently, users can engage more effectively with the material via videos that incorporate animations and sound features not possible with traditional, paper-based materials.

Implementation Results

Practicality Test Results

The implementation phase of this module involved applying it in the classroom with students enrolled in the trigonometry course. The lessons were conducted by the researcher, who also served as the course instructor. After the lessons, a survey was administered to 62 students (from Class A and Class B) to assess the usability of the module from the students' perspective. The results of the usability survey were analyzed to provide an overview of how the module was perceived by the students. The findings from this analysis of practicality are presented in Table 5.

Table 5. Practicality Test Results of the Module

Item	Question	Score	Description
1	Digital module display	4.33	Very Practical
2	Access to instructional videos	3.45	Practical
3	Access to LiveWorksheet	4.19	Practical
4	Coherence of the learning process	4.23	Very Practical
5	Clarity of project information	4.11	Practical
Average			4.30

The data presented in Table 5 indicate that each aspect of usability met the criteria for being either practical or very practical. The analysis suggests that the instructional module meets the practicality standards. This means, based on the students' perceptions, that the digital trigonometry module is user-friendly. Educational materials are deemed practical when they are easy to use in real-world settings (Akbar, 2013; Nieveen & Folmer, 2013).

When evaluating the practicality of instructional materials in the classroom, it is important not only to consider numerical ratings but also to incorporate written feedback from users after they have used the module. In this study, feedback was generally positive, though some suggestions for improvement were provided. These included adjustments to the speed of the instructional videos, as well as addressing issues with blurry images and unclear text. The responses to these usability concerns led to revisions, resulting in a finalized version of the module.

Effectiveness Test Results

The digital module was implemented over two class sessions (2 x 100 minutes). The time allocation adhered to the university's curriculum, where one semester credit (1 SKS) corresponds to 50 minutes of face-to-face instruction. The students, who had committed to the trigonometry course, were selected as subjects for the effectiveness test. During the class sessions, it was ensured that students had the requisite prior knowledge to support the material covered in the module, as the module focused on applying trigonometry to real-world problems. Ensuring that students mastered the foundational concepts was essential for bridging their understanding of the content presented in the digital module.

After the two class sessions, students were given a post-test to assess their mathematical communication skills. The test consisted of four open-ended questions. The results were analyzed to measure the impact or effectiveness of the digital module in the classroom. The students' scores were then corrected and converted to a 0-100 scale.

Table 6. Mathematical Communication Skills Data Description

Statistic	Value
Minimum	44.50
Maximum	90.25
Mean	65.25
Standard Deviation	6.80

Table 6 shows that the average student score after using the digital trigonometry module was 65.25. When converted to a 0-100 scale, this indicates that, on average, students achieved over 65% proficiency in mathematical communication skills. This data suggests that the use of the module had a positive effect on students' ability to communicate mathematically. The skill levels were further analyzed and categorized, as shown in Table 7.

Table 7. Student's Mathematical Communication Skill Levels

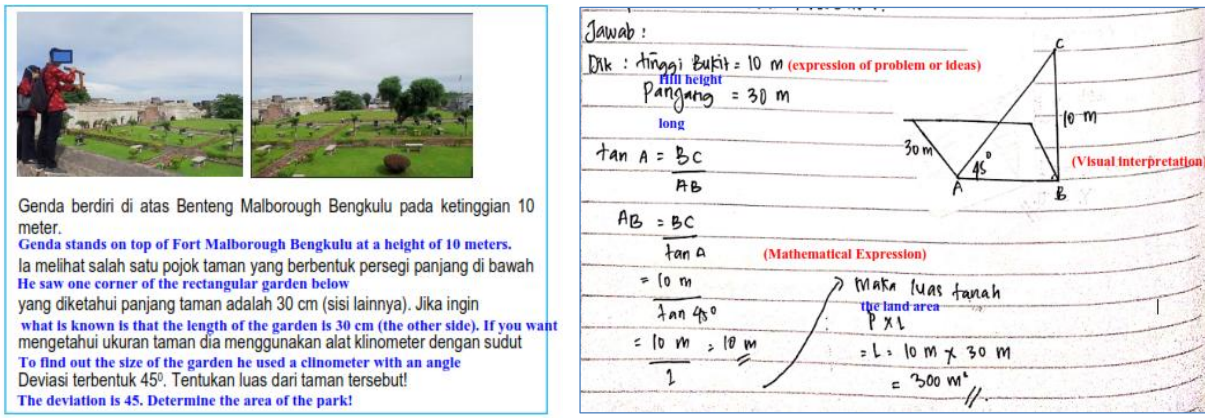
Score Intervals	Criteria	The number of students	Percentage
0-33	Low	11	17.74 %
34-66	Medium	36	58.07 %
67-100	High	15	24.19 %

The data presented in Table 7 reveal that over 80% of students demonstrated medium to high levels of mathematical communication skills. This suggests that the use of the digital trigonometry module effectively enhanced students' ability to communicate mathematically.

Furthermore, students' responses to solving real-world problems, such as those involving elevation angles and deviations, were commendable.

Evaluation Results

This was evident in their performance on the post-test, where they progressively solved problems in accordance with the indicators of mathematical communication. One example of students' responses to a mathematical communication problem is illustrated in Figure 5.



(a) (b)

Figure 5. Example of Student Response (a) Problem, (b) Solution

The figure above demonstrates that students were able to formulate an expression based on the given problem. This was evident from the details they identified within the problem, even though they did not explicitly state the exact question. In the subsequent stage, students successfully visualized the problem geometrically, which is essential for effective communication skills. Accurate visualization requires a comprehensive understanding of the problem's details, and this step is crucial in problem-solving. The next stage involved the mathematical expression of the problem, where students performed the necessary calculations correctly using appropriate mathematical operations. Overall, the findings of this study show a significant improvement in students' mathematical communication skills as a result of using the developed digital module, with the average skill level categorized as medium.

In summary, this research indicates that digital-based instructional materials positively influence students' mathematical communication abilities. These results are consistent with prior studies that suggest the use of digital modules can enhance students' learning outcomes. This study aligns with the findings of (Susanto & Susanta, 2022), who reported that interactive modules promote student literacy and self-confidence. Furthermore, digital modules have been shown to enhance problem-solving skills (Permana et al., 2021). The role of digital modules is crucial in facilitating diverse learning experiences for students. The content presented in the module is easily accessible and caters to a variety of learning styles, including visual and auditory preferences. Additionally, the use of animations and other engaging presentation formats can enhance student motivation. These findings are also supported by research from (Rohmaini et al., 2020), which suggests that engaging instructional materials improve students' retention of the course material.

CONCLUSION

Based on the findings and discussions presented above, it can be concluded that the LiveWorksheet-based digital trigonometry module meets the validity criteria set by expert evaluations. Additionally, this digital module has been deemed practical according to student perceptions and effective in improving students' mathematical communication skills. Future research could focus on enhancing the module by incorporating additional online practice features.

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