Mobile learning innovation to improve vocational high school students'mathematical communication skills and dispositions

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Abstract

Students require engaging and relevant instructional materials to enhance their mathematical communication skills and mathematical dispositions. This study aims to develop mobile learning-based instructional materials on matrix topics integrate mathematical communication and disposition for vocational high school students. The research employed a Research and Development (R&D) method with a mixed-method approach, following the 4D development model: define, design, develop, and disseminate. The trials were involved 8 subject matter experts and 8 media experts, as well as 15 grade XII AP students for small-group trials and 30 grade XI AP students for large-group trials at SMK Bina Sarana Industri Subang. Data were collected through interviews, questionnaires, and tests. The results indicate that the mobile learning materials on matrix topics are of acceptable quality and received positive responses in terms of students' mathematical dispositions. However, no significant correlation was found between students' mathematical communication skills and their mathematical dispositions. These findings suggest the need for further development in integrating mathematical communication and disposition into instructional materials.

Keywords: Digital Learning, Mathematical Communication, Mathematical Disposition, Mixed-Method, Mobile Learning.

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INTRODUCTION

Mathematical communication skills are among the essential competencies students need to master in order to succeed in solving daily problems and to face the challenges of the digital era. Hodges et al. (2020) and Dhawan (2020) indicate that technology-based learning, such as blended learning, can enhance students' communication skills through more interactive and collaborative approaches. Furthermore, Favale et al. (2020) and Nugraha (2024) argue that this skill is also closely related to students' understanding of complex mathematical content. Rachmawati et al. (2022) and Yaniawati et al. (2022) reveal that learning designed with multimedia technology can facilitate better comprehension of mathematical concepts. In addition, Tiffany (2017) and Juliandarini et al. (2023) emphasize that mobile learning-based teaching materials are capable of increasing student engagement and motivation to learn.

Despite various efforts, Indonesian students' mathematical communication skills remain relatively low, as reflected in the results of TIMSS (Trends in International Mathematics and Science Study). Romdona (2018) and Setyadi (2021) reveal that one of the main factors contributing to this issue is the

lack of engaging and interactive teaching materials. Additionally, Nugraha and Wahyuni et al. (2022) highlight that traditional lecture-based teaching methods hinder students' understanding of abstract mathematical concepts. Widodo et al. (2021) and Putra & Yuliana (2023) suggest that the absence of technology-based learning media contributes to low levels of student creativity and communication skills. Yaniawati and Indrawan (2024) also point out that teachers continue to face challenges in effectively integrating technology into mathematics instruction.

Students need engaging and interactive teaching materials to develop their mathematical communication skills. Widodo et al. (2021) and Juliandarini et al. (2023) suggest that face-to-face learning is more effective than online learning, although blended learning offers greater flexibility (Rachmawati et al., 2022; Setyawan et al., 2023). According to Nugraha and Andriana (2024), the impact of technology in education is heavily influenced by student readiness, as also emphasized by Favale et al. (2020) and Wahyuni et al. (2022). Hodges et al. (2020) and Yaniawati & Indrawan (2024) add that educational technology can improve student engagement when designed with consideration for psychological aspects and learning motivation.

Moreover, Dhawan (2020) and Sari et al. (2022) report that mobile learning supports student autonomy by offering flexible access to learning resources. Rachmawati et al. (2021) and Putra & Yuliana (2023) highlight that multimedia-based instructional design not only enhances concept comprehension but also increases students' interest in mathematics. Yaniawati et al. (2022) and Mustakin (2020) note that technology-based blended learning is highly effective in improving students' critical and analytical thinking skills. Meanwhile, Tiffany (2017) and Anku (2019) state that technology helps students visualize abstract mathematical concepts through various representations.

Romdona (2018) and Setyadi (2021) suggest that the low TIMSS performance among Indonesian students can be addressed through technological innovations such as mobile learning applications. Nugraha (2024) and Wahyuni et al. (2022) affirm that technology can enhance students' mathematical disposition, including their self-confidence. Similar findings were reported by Juliandarini et al. (2023), who found that students with access to application-based learning showed significant improvements in their mathematical communication skills. Yaniawati and Indrawan (2024) emphasize that in-depth interviews can be used to evaluate the impact of technology on students' learning experiences.

According to Hodges et al. (2020) and Dhawan (2020), well-planned online learning can minimize technical and communication barriers between students and teachers. Favale et al. (2020) and Setyawan et al. (2023) reveal that individual differences in adapting to technology significantly influence learning outcomes, especially during the transition from online to in-person learning. Rachmawati et al. (2022) and Nugraha (2024) show that application-based blended learning helps students achieve a deeper understanding of the material. Meanwhile, Tiffany (2017) and Juliandarini et al. (2023) argue that mobile learning-based instructional materials allow students to learn at their own pace, thereby improving their confidence.

This study aims to develop technology-based teaching materials that can enhance students' mathematical communication skills. According to Dhawan (2020) and Rachmawati et al. (2022), these materials will be designed using an interactive multimedia approach to support a more engaging learning process. Hodges et al. (2020) and Juliandarini et al. (2023) state that the materials will be tailored to students' needs to increase their learning motivation. Another goal is to evaluate the effectiveness of the materials in helping students understand abstract mathematical concepts, as highlighted by Nugraha (2024) and Wahyuni et al. (2022). Therefore, this study is expected to contribute to improving the quality of mathematics education in Indonesia.

METHODS

The research method used is *the* Research and Development (R&D) method with a mixed method approach with quantitative and qualitative approaches to develop interactive mobile learning teaching materials, aiming to improve students' mathematical communication skills and mathematical disposition. The research design follows a 4D model by Yaniawati (2024), which consists of four stages: definition, design, development, and deployment. This model is designed to produce teaching materials that are effective and appropriate to the needs of students, starting with a needs analysis to determine the goals and competencies to be achieved. This research aims to provide a comprehensive overview of the teaching material development process.

At the definition stage, a needs analysis is carried out to determine the expected goals and competencies based on current learning conditions. The design stage involves the preparation of teaching materials taking into account aspects of interactivity and ease of use, which is expected to increase active student engagement. Material

Teaching is designed so that students can more easily understand the material and be more motivated to discuss. After that, at the development stage, the teaching materials that have been designed are tested on a limited basis and validated by material experts and media.

The limited trial aims to evaluate the effectiveness of teaching materials in improving students' mathematical communication skills. The instrument trial process involves several stages, namely content validation by experts to ensure that the instrument is in accordance with the research objectives, a small group trial with 15 students to measure the clarity of the questions and the readability of the questionnaire, and a reliability test using statistical analysis to ensure the consistency of the instrument. The instruments used included a questionnaire of students' responses to mobile learning teaching materials, a mathematical communication ability test to measure the improvement of student understanding, and a mathematical disposition questionnaire to assess students' attitudes and interest in mathematics after the use of teaching materials. The revision was carried out based on the results of the trial and input from 8 material experts and 8 media experts to ensure the feasibility of the material and media used. At the deployment stage, the teaching materials were tested in real learning conditions with large groups of 30 students to measure the long-term impact on student learning outcomes. The results of the trial and analysis provide information for the improvement of teaching materials before they are applied on a wider scale.

The implementation of the research at SMK Bina Sarana Industri Subang with participants of class XI students in odd semesters. Quantitative data was collected through mathematical communication ability tests, while qualitative data was obtained through expert validation questionnaires and in-depth interviews. Inferential statistical tests, such as the t-test, are used to compare students' test results before and after the use of teaching materials. Qualitative analysis is used to evaluate students' responses to teaching materials, and the results will be used for further improvement. The questionnaire assessment criteria will then be classified as shown in Table 1 below.

Table 1. Questionnaire Assessment Criteria

Rumus	Average Score	Classification
$x > \bar{x}i + 1{,}8\ x\ sbi$	> 4,2	Highly Worth It
$\bar{x}i + 0{,}6\ \times\ sbi < x \leq \bar{x}i + 1{,}8 \times sbi$	3,4 < x ≤ 4,2	Proper
$\bar{x}i - 0{,}6\ \times\ sbi < x \leq \bar{x}i + 0{,}6 \times sbi$	2,6 < x ≤ 3,4	Enough
$\bar{x}i - 1{,}8\ \times\ sbi < x \leq \bar{x}i + 0{,}6 \times sbi$	1,8 < x ≤ 2,6	Less Worthy
$x > \bar{x}i - 1{,}8 \times$ sbi	≤ 1,8	Very Less Worthy

RESULTS AND DISCUSSION

The development of mobile learning teaching materials on matrix materials at SMK Bina Sarana Industri Subang follows the 4D model (Define, Design, Develop, Disseminate) to produce valid, practical, and effective teaching materials in improving students' communication skills and mathematical disposition. The analysis of learning needs is carried out through questionnaires and interviews with students and teachers, which showed that 70% of students scored below the minimum completeness criteria on the matrix material, thus demonstrating the need for more interactive and engaging teaching materials, such as communication-based mobile learning and mathematical disposition. The design phase involves the creation of an initial draft of a mobile application-based module that includes comprehensive materials, instructions for use, basic competencies, learning objectives, and practice questions, including quizzes and posttests, as well as questionnaire instruments for expert validation and measurement of student responses. In the develop stage, expert validation of the content and media ensures the feasibility and effectiveness of the module, followed by a small group trial with grade XI students who showed positive responses regarding ease of use, interest in content, and clarity of material. The disseminate phase involves the dissemination of mobile learning modules after they have been declared valid, practical, and effective, with the results of the trial showing an increase in students' understanding of matrix concepts and their mathematical communication skills, as well as support from practice questions, quizzes, and posttests that strengthen understanding through repetitive exercises.

Use of Mobile Devices

The use of mobile devices allows for more flexible learning, as students can access the material at any time, in line with the findings of Rosyida et al. (2023) who developed a mobile module for graph theory learning, which helps improve students' creative thinking processes. Research by Mukti et al. (2024) found that problem-based learning models can improve students' critical thinking skills, while Taufik and Vandita (2023) show that students' metacognition abilities can be improved through appropriate learning approaches, supporting the effectiveness of using mobile technology in mathematics learning. However, for wider implementation, support from schools is needed, especially in providing facilities and training for teachers to make the most of these teaching materials (Laswadi, 2023; Nikmah et al., 2020).

Mobile Learning Application Validation Results

The results of the study show that mobile learning applications meet good feasibility standards in mathematics learning, as seen from the suitability of the material with Basic Competencies, relevance, and up-to-date information, in line with Cavanaugh et al. (2004) and Lin et al. (2016) who stated that technology in learning can increase students' active engagement.

This mobile learning application is also able to encourage students' curiosity and provide motivation for further exploration, with research by Wang and Xie (2021) and Lin et al. (2022) finding that the use of technology in mathematics learning can increase students' confidence and understanding, although some students with low abilities still find it difficult to understand mathematical concepts through this application.

Students' responses to online learning during the pandemic showed variations based on their level of understanding, where students with lower abilities feel less motivated (Zhao et al., 2021), while superior students see online learning as a positive innovation and feel more focused (Martin et al., 2020). Some students revealed that the material in the package book is still lacking contextual, and Vassallo & Micallef

(2021) stated that irrelevant material can reduce learning effectiveness, so that mobile learning-based teaching materials are considered easier to understand by students, especially those with low abilities.

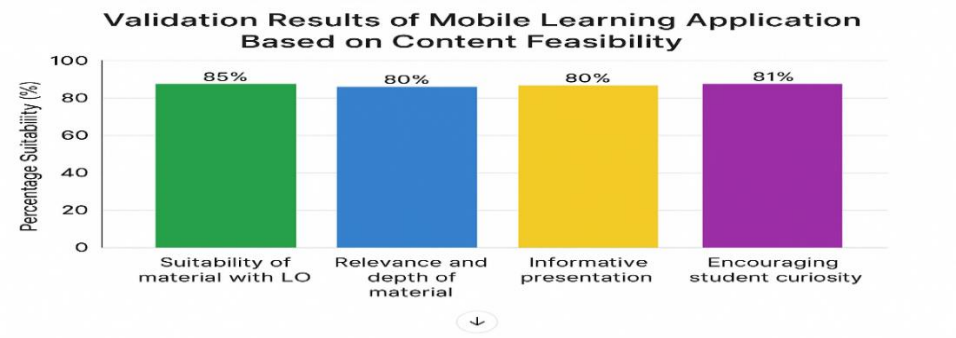

Figure 1. Results of Mobile Learning *Application Validation* Based on Content

Feasibility The results of the study show that the mobile learning application meets the standards good feasibility in mathematics learning, as can be seen from the suitability of the material with the Basic Competency (KD), relevance, and up-to-date information, in line with Cavanaugh et al. (2004) and Lin et al. (2016) who stated that technology in learning can increase students' active involvement.

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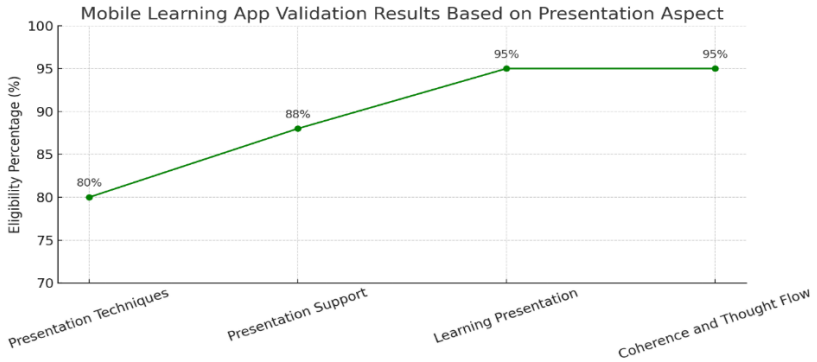

Figure 2. Mobile Learning App Validation Result Based on Presentation Aspect

Validation Based on Presentation Aspects The results of the mobile learning application validation show that the presentation aspect has been very well designed. This contributes to improving the overall student learning experience. Similarly, some research found that mobile learning applications are able to compose content coherently. This good content preparation facilitates a better understanding of concepts for students. In addition, another research showed that Android-based Mathematics Mobile Learning applications improve students' numeracy literacy. The presentation of

well-structured material is one of the key factors in this achievement.

Sari et al. (2020) stated that intuitive interface design in mobile learning applications supports logical and effective learning flows. The support of presentation elements, such as visualization and interactivity, also plays an important role in helping students understand the concepts being taught. Kwangmuang et al. (2021) emphasize that these elements can increase student engagement in the learning process. Although the presentation technique received the lowest score, this aspect was still considered feasible because the visual presentation and sample questions provided were able to actively engage students.

The findings of Olis et al. (2023) also emphasize the importance of active student involvement through interactive elements. Thus, despite some shortcomings in presentation techniques, this mobile learning application still has great potential to improve student understanding. The use of proper presentation elements can help create a more engaging and effective learning experience.

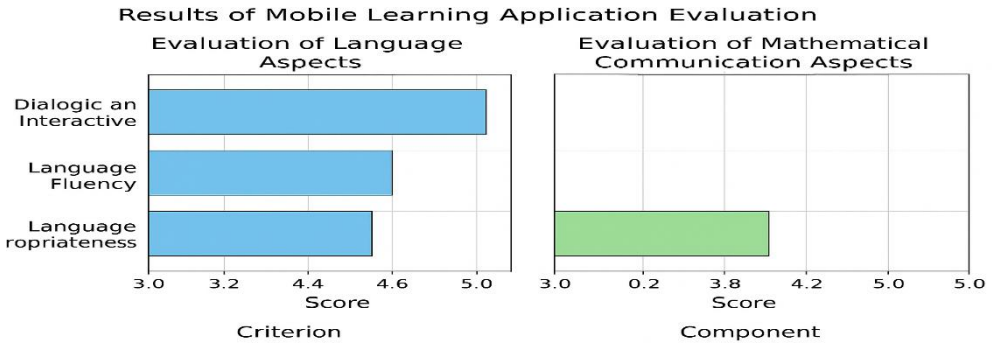

Figure 3. Results of *Mobile Learning Application Evaluation*

Results of Evaluation of Linguistic Aspects and Mathematical Communication

The results of the evaluation showed that the mobile learning application developed had met good feasibility standards in the aspects of language and mathematical communication. The app has proven to be effective in supporting student engagement and understanding of math concepts. Some reaserch emphasized that the use of language that is straightforward and appropriate to the student's cognitive level can improve the understanding of mathematical concepts. This is in line with the findings of many research who show that good mathematical communication in digital applications helps students articulate their understanding more systematically.

Pratama et al. (2022) highlight the importance of interactive media in mathematics learning to increase student participation. Dewi et al. (2022) also found that mobile learning applications that present material dialogically are able to increase concept retention in students. In addition, Setiawan and Hidayat (2020) confirm that effective mathematical communication in digital-based applications can help students connect abstract concepts with real representations. These findings suggest that good interaction in the app can strengthen students' understanding of the material being taught.

Putra and Santoso (2021) show that mobile applications based on adaptive technology help students understand the material according to their respective learning speeds. Susanto (2022) supports these findings by stating that apps designed to be interactive and based on real context can increase students' motivation to learn mathematics. Karim and Hakim (2020) added that visual communication in digital applications contributes greatly to a deeper understanding of mathematical concepts. Thus, this app not only improves comprehension, but also motivates students to study harder.

Table 2. Test Statistics

N	8
Cochran's Q	5.160a
Df	3
Asymp. Sig.	.160

Results of Teaching Material Validation Test

The results of the Cochran test showed that there was no significant difference in validators' assessment of the teaching materials, indicating that these teaching materials met consistent and objective standards of eligibility. Suryani and Sukma (2019) emphasized that expert validation is an important step to ensure the quality of teaching materials in accordance with the expected standards. Consistent assessments from validators show that the material prepared is in accordance with the curriculum and can be well understood by students.

Hidayah and Rohman (2021) show that a coherent material structure and an attractive layout are very important in supporting student understanding. Fatmawati (2018) also highlights the importance of alignment between materials and basic math concepts, which allow students to more easily connect new knowledge with existing ones. Thus, the aspect of presenting the material is key in increasing the effectiveness of learning.

Aminah (2022) shows that the consistent and easy-to-read use of letters increases student comfort when learning using digital teaching materials. Setiawan and Yuliana (2021) added that the use of animation in teaching materials can enrich students' learning experiences and attract their attention. Andriana et al. (2020) state that interactive elements such as animations can help students understand difficult concepts in a more fun way. This shows that interactive elements play an important role in creating an engaging and effective learning experience.

Alfiansyah and Rusdiana (2019) revealed that after improvements based on validator input, teaching materials become more effective in achieving learning goals. Tanjung (2021) added that teaching materials that have gone through a validation and improvement process can be applied more confidently in learning. This validation and improvement process is very important to improve the quality of teaching materials, so that the teaching materials produced not only meet high feasibility standards, but can also have a positive impact on student learning.

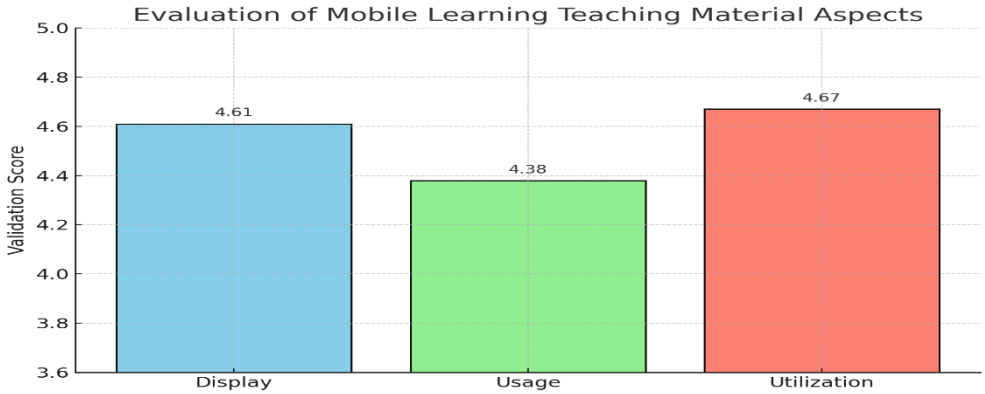

Figure 4. Evaluation of Aspects of *Mobile Learning Teaching Materials*

Results of Validation of Mobile Learning Teaching Materials

The validation results show that visual design, interactivity, and language simplicity in mobile learning teaching materials can increase students' interest and understanding of mathematics materials. Suryani and Sukma (2019) emphasized that attractive design plays an important role in increasing students' motivation to learn. In addition, Hidayah and Rohman (2021) show that the linkage of the material to students' daily lives is essential to strengthen their understanding.

Fatmawati (2018) revealed that the use of simple and clear language makes it easier for students to access information. Aminah (2022) shows that an easy-to-use login system and an attractive appearance support ease of access

to teaching materials, so that students do not experience technical obstacles while learning. Setiawan and Yuliana (2021) added that memory-saving applications are very helpful for students, especially for those who have device limitations. In addition, Alfiansyah and Rusdiana (2019) emphasized the importance of improvement based on user input to increase the effectiveness of teaching materials, and Tanjung (2021) added that teaching materials that have been validated and improved can be applied more confidently in the learning process.

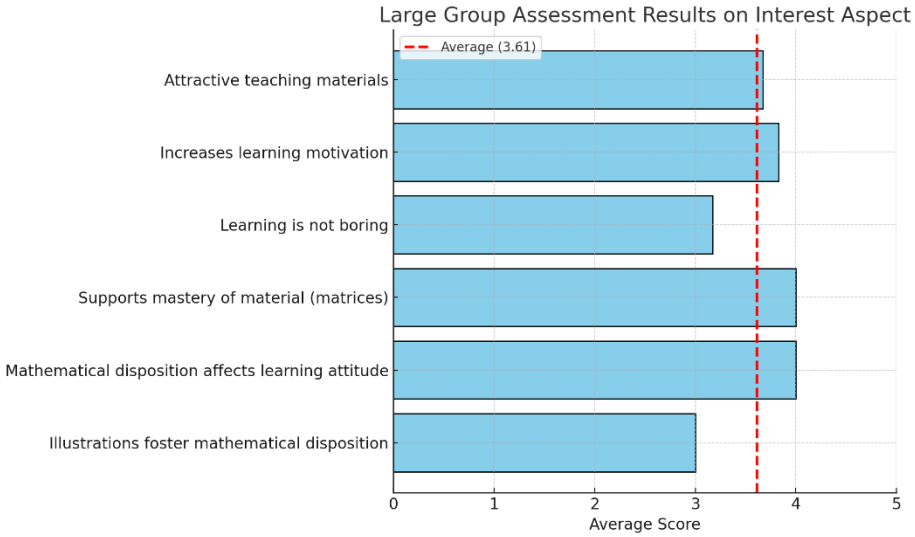

Figure 5. Results of Large Group Test Assessment on Interest Aspects

Results of Evaluation of Aspects of Interest in Teaching Materials

The results of the evaluation show that the display design and content of teaching materials are able to support students in understanding mathematics material, especially matrix material. This teaching material has a positive impact on students' learning attitudes through improving mathematical disposition. Suryani and Sukma (2019) emphasize the importance of attractive visual design to attract students' attention. However, Hidayah and Rohman (2021) revealed that less in-depth illustrations can limit students' understanding, so improvements are needed to enrich the learning experience through more meaningful visualization.

Susanti et al. (2020) stated that material that is presented visually with a clear display can strengthen students' understanding of the concepts taught. Aminah (2022) adds that attractive displays can increase student motivation, but the use of more interactive visual elements will be much more effective. Setiawan and Yuliana (2021) highlight the importance of choosing relevant and easy-to-understand illustrations to deepen students' understanding. Andriana et al. (2020) suggest the use of

visual elements such as animations and interactive graphics to clarify abstract concepts in mathematics. Tanjung (2021) argues that the increase in

Visual and interactive elements not only help with comprehension, but can also increase students' motivation to learn optimally.

Table 3. Results of Large Group Test Assessment on Material Aspects

No	Indikator	Average
1	Delivery of material in mathematical communication-based Mobile Learning teaching material related to everyday life.	3,4
2	Materials presented in Mobile learning teaching materials is easy for me to understand	4,4
3	Mathematical Communication Based-Mobile Learning teaching materials is the section for me to find my Self-Concept	3,8
4	Delivery material at mathematics prompted me to discuss with other friends.	4,4
5	This contains an evaluation test that can test how far I understand about matrix material.	4,0
	Average Score	4,0

Results of Evaluation of Material Aspects

The results of the evaluation showed that this mobile learning teaching material succeeded in presenting content that was easy for students to understand, as well as encouraging them to discuss and improve their understanding of the concept. Hidayah and Rohman (2021) emphasized that clear delivery of material is very important to help students understand difficult concepts. Another research also suggested that materials that encourage collaboration between students can deepen their understanding and develop their social skills. However, there is a need to increase the relevance of the material to students' daily lives so that their understanding is deepened.

Fatmawati (2018) emphasized the importance of associating the material with a familiar context for students to improve understanding. Aminah (2022) revealed that material relevant to real life is more interesting and can increase students' motivation to learn. Setiawan and Yuliana (2021) emphasized that the relevance of the material to the everyday context is very important so that students can see the practical usefulness of what they learn. Tanjung (2021) suggested that the development of material relevance not only increases student engagement, but also accelerates their understanding of concepts, so that the development of teaching materials needs to be continuously refined to be more contextual and meaningful.

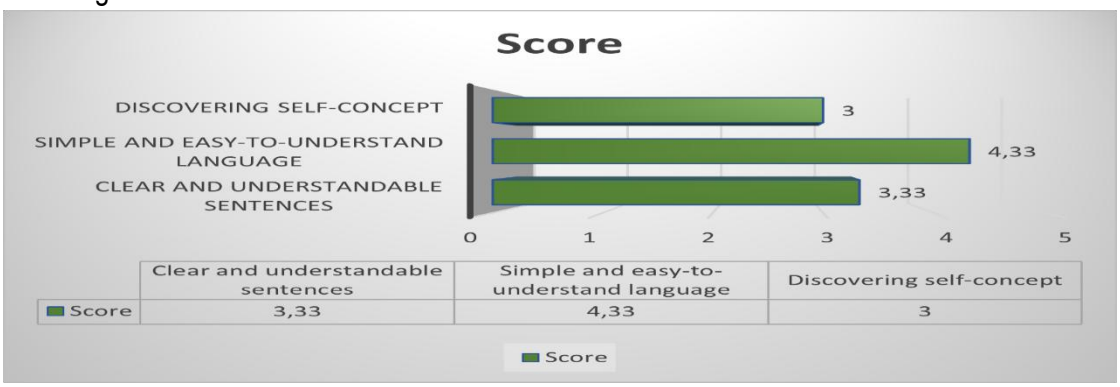

Figure 6. Results of Large Group Test Assessment on Language Aspects

Eligibility of Mobile Learning Teaching Materials

Mathematical communication-based mobile learning teaching materials show good feasibility, especially in the aspect of material that is easy to understand and able to encourage discussion between students. Hidayah and Rohman (2021) emphasized that the design of attractive teaching materials can increase students' interest in the material. However, there is a need to improve visual illustrations to better support the development of students' mathematical dispositions, in accordance with the opinion of Fatmawati (2018) regarding the importance of proper visualization.

Input from media experts suggests that teaching materials can be accessed through the Play Store, which is in line with the opinion of Setiawan and Yuliana (2021) about the importance of application accessibility to facilitate use by students. Aminah (2022) also suggested improving visual elements to be more attractive and able to increase students' interest in learning. Tanjung (2021) added that improvements based on user feedback are essential to improve the quality and effectiveness of teaching materials in an ongoing manner.

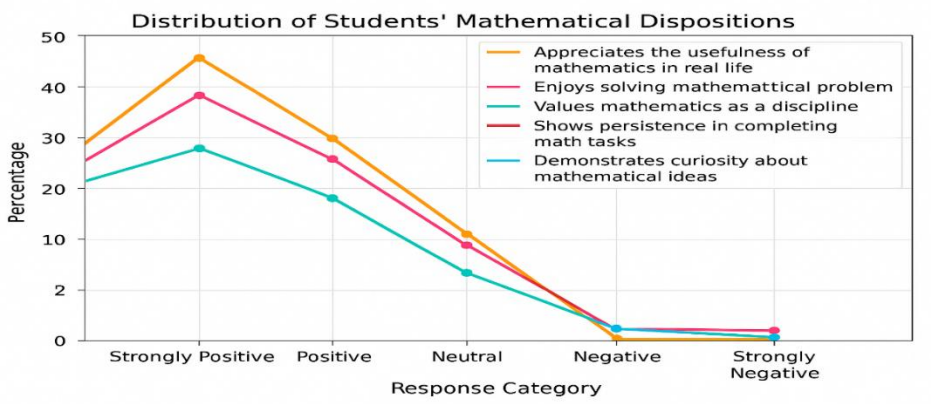

Figure 7. Percentage Distribution of Students' Mathematical Dispositions

Students' Responses to Math Relevance

The findings show that students respond positively to the relevance of mathematics in everyday life, which has an impact on their increased interest and appreciation of these subjects. Hidayah and Rohman (2021) emphasized the importance of linking the material to real life to help students understand the benefits of mathematics, while Fatmawati (2018) added that such associations can increase students' interest. Setiawan and Yuliana (2021) emphasized the importance of strategies to increase student motivation so that the mathematics learning process is more optimal, ensuring that students not only understand concepts but are also motivated to learn further.

Results of Mobile Learning Teaching Materials Development

Mobile learning teaching materials in matrix materials have been successfully developed with a very feasible category, both in terms of content and media, based on the results of expert validation and tests on students. The use of these teaching materials has been proven to be effective in improving students' mathematical communication skills, which is shown by the increase in post-test scores compared to pre-tests. In addition, students show positive responses to mathematical dispositions, such as increased confidence, motivation, and perseverance in learning mathematics. However, correlation analysis showed that there was no significant relationship between mathematical communication skills

and students' mathematical disposition.

The absence of a significant correlation between a student's mathematical communication ability and mathematical disposition is due to several factors. First, although students show improvements in mathematical communication, their mathematical disposition may be influenced by external factors such as the learning environment, social support, or previous experiences in learning mathematics (Hidayah & Rohman, 2021).

CONCLUSION

Mobile learning teaching materials in matrix materials have been successfully developed with a very feasible category, both in terms of content and media, based on the results of validation from experts and trials conducted on students. The use of these teaching materials has been proven to be effective in improving students' mathematical communication skills, which can be seen from the increase in post-test scores compared to pre-tests. In addition, students show a positive response to mathematical disposition, such as increased confidence, motivation, and perseverance in learning mathematics. However, correlation analysis showed that there was no significant relationship between mathematical communication skills and students' mathematical disposition. This research shows that mobile learning teaching materials can be an effective learning alternative to improve students' mathematical communication. The practical implication for vocational school teachers is the importance of integrating mobile learning teaching materials in the learning process to support the improvement of students' mathematical communication skills. The recommendation for further research is to explore more deeply the relationship between communication and mathematical disposition, in order to understand the factors that affect the two and how they can be mutually supportive in the context of mathematics learning. Conclusions should answer the objectives of research. Tells how your work advances the field from the present state of knowledge. Without clear Conclusions, reviewers and readers will find it difficult to judge the work, and whether it merits publication in the journal. Do not repeat the Abstract, or just list experimental results. Provide a clear scientific justification for your work and indicate possible applications and extensions. You should also suggest future experiments and/or point out those that are underway.

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