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DEVELOPMENT OF AN INTERACTIVE VISUALIZATION APLICATION TO ASSIST VOCATIONAL STUDENTS IN UNDERSTANDING TRIGONOMETRY CONTENT

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Abstrak

Trigonometri adalah kompetensi kunci bagi siswa vokasi karena aplikasinya yang luas dalam desain teknik, arsitektur, dan bidang industri, tapi temuan empiris menyoroti hambatan visualisasi yang signifikan. Penguasaan konsep dasar ini terhambat oleh kesulitan siswa dalam memvisualisasikan perbandingan segitiga siku-siku, terutama ketika segitiga tersebut disajikan dalam posisi yang tidak standar. Untuk mengatasi tantangan ini, penelitian ini berfokus pada pengembangan aplikasi visual interaktif, yaitu AVIGO. AVIGO dirancang secara spesifik, berbeda dengan GeoGebra yang memiliki fungsi luas, atau aplikasi edukasi berbasis Android lain yang hanya menyajikan materi statis. Pembeda utama AVIGO adalah integrasi fitur rotasi segitiga dinamis yang memungkinkan siswa mengubah orientasi segitiga secara dinamis, secara langsung menghubungkan perubahan sudut dengan rasio sisi yang sesuai. Penelitian ini menggunakan pendekatan R&D dan melibatkan uji coba efektivitas dengan 52 siswa vokasi terpilih. Hasil pengujian menunjukkan Skor Efektivitas Keseluruhan AVIGO mencapai 3,22. Skor ini mengindikasikan bahwa aplikasi dinamis ini sangat efektif dalam memfasilitasi pemahaman konseptual dan mendorong motivasi belajar. Secara spesifik, item angket mengenai fitur rotasi segitiga mendapatkan skor tinggi (3,19), menegaskan bahwa visualisasi dinamis sangat membantu siswa mengatasi kesulitan pemecahan masalah. Kesimpulannya, AVIGO layak direkomendasikan sebagai media pembelajaran interaktif yang tidak hanya memperkuat penguasaan perbandingan trigonometri, tetapi juga mendorong pembelajaran aktif dan bermakna di pendidikan vokasi.
Kata kunci: Pemahaman Konseptual; Visualisasi Interaktif; Motivasi Belajar; Trigonometri.

Abstract

Trigonometry is a vital competency for vocational students due to its wide applications in engineering, architecture, and industrial fields. However, empirical studies highlight significant challenges in visualizing trigonometric concepts, particularly when right triangles are presented in non-standard orientations. To address this issue, this study developed an interactive visual application called AVIGO. Unlike multipurpose software such as GeoGebra, which offers broad mathematical functionalities, or other Android-based educational tools that display only static content, AVIGO is specifically designed to enhance conceptual understanding through dynamic visualization.

Its key innovation lies in the integration of a triangle rotation feature, allowing students to manipulate the triangle's orientation in real time and directly relate changes in angles to corresponding side ratios. This study employed a R&D approach and involved 52 selected vocational students in its effectiveness testing. Results showed an overall effectiveness score of 3.22, indicating that AVIGO is highly effective in fostering conceptual comprehension and motivation to learn. Moreover, the triangle rotation feature received a high score (3.19), confirming that dynamic visualization significantly supports students in overcoming problem-solving difficulties. In conclusion, AVIGO is recommended as an innovative and interactive learning medium that not only strengthens understanding of trigonometric ratios but also promotes active and meaningful learning in vocational education.
Keywords: Conceptual Understanding; Interactive Visualization; Learning Motivation; Trigonometry.

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INTRODUCTION

Trigonometry, as an extension of geometry, plays a crucial role in mathematics and its applications across diverse fields such as engineering design, navigation, architecture, and industrial measurement (Arce Sánchez et al., 2023). It relies fundamentally on visual reasoning to represent and interpret relationships between angles and sides of triangles. Yet, many vocational students find it challenging to visualize right triangles, particularly when presented in non-standard orientations, a difficulty that often impedes their conceptual understanding. From a pedagogical standpoint, strengthening students' visualization ability is therefore essential, not only to improve their problem-solving performance but also to cultivate deeper mathematical reasoning, creativity, and engagement in learning trigonometric concepts.

Trigonometry is a fundamental concept that is also used in other subjects such as geometry, algebra, and graphics (Sarac & Aslan Tutak, 2017). Trigonometry is often used together with geometry to calculate the relationships between angles and circles. This helps students develop cognitive strategies, such as problem-solving skills through reasoning and proof abilities (Phonapichat et al., 2014). However,

despite its broad application and conceptual richness, trigonometry remains one of the most abstract and visually demanding topics for learners. The shift from concrete geometric representations to symbolic reasoning often becomes a major barrier to students' conceptual understanding. Trigonometry material is also used when students study calculus. Therefore, problem-solving in trigonometry is considered very difficult for students (Ernaningsih & Wicasari, 2017). According to Nurmeidina & Rafidiyah (2019) , students' difficulties in solving trigonometry problems are due to their lack of understanding of the concepts and low motivation to learn.

Although trigonometry plays an essential role in developing students' mathematical reasoning, its abstract nature often makes it challenging for learners to grasp the underlying concepts. This conceptual gap between the visual and symbolic representations of trigonometric relationships has been identified as one of the main factors contributing to students' learning difficulties. Students' learning difficulties in studying trigonometry are experienced by many learners. Obeng et al (2024) identified students' difficulties in solving trigonometry problems related to transformation, processing skills, and understanding. Sánchez et al (2023) state that students often have difficulty solving trigonometric ratio problems. Students have difficulty using trigonometric ratios to find angles of elevation and depression, and when given an angle and the length of one side of a right triangle, students struggle to use the formula to calculate the length of the other side. Asomah et al (2023) and Nanmumpuni & Retnawati (2021) identified students' difficulties in solving conceptual trigonometry problems. Students' difficulties in mathematical connections when solving two-dimensional trigonometry problems (Kgaladi et al., 2023). The identified difficulties result in poor learning outcomes in trigonometry.

Various studies have been conducted to help students learn trigonometry with the aim of motivating them. Motivation has a significant impact on mathematics learning, so it can be said that if motivation is neglected, mathematics teaching will not be effective (Defi & Qohar, 2022). One of the media that helps increase

motivation is the use of technology in learning. The technology used in learning greatly supports students in achieving optimal learning (McLaren et al., 2022; Rebollo et al., 2022; Wang et al., 2022; Zaneta, 2022). Mastery of technology can be achieved well if one also has good mathematical competence (Asfar & Asfar, 2020). Technology-oriented classrooms are reliable and accommodating tools in assisting the teaching process and understanding of mathematical concepts (Bekene Bedada & Machaba, 2022).

One of the technologies that can help students learn trigonometry is the GeoGebra software. GeoGebra helps address several problems faced by students in trigonometry, including difficulties in making connections between conceptual representations (Mosese & Ogbonnaya, 2021) and assisting students who have incomplete or fragmented ways of viewing trigonometric functions and interpreting function graphs. GeoGebra helps teachers in teaching trigonometric functions, trigonometric ratios, angles, radians, and the concept of the Pythagorean theorem (Joshi, 2022) Another technology used to assist in understanding trigonometric functions is Android-based applications (Asmianto et al., 2022; Hidayat et al., 2023). The technology used aims to help students visually with trigonometry material.

From the researchers' observations, many students still have difficulty visualizing the position of a right triangle, which is a fundamental concept in trigonometry. Understanding the concept of right triangles is important in studying trigonometry (Theses et al., 2019). Adhikari & Subedi (2021) state that teacher preparation in knowledge, ideas, and methods of teaching trigonometry is an important variable for conducting meaningful, effective learning and reducing students' difficulties in studying it. In fact, mathematics teachers often introduce trigonometric ratios to students by drawing many right triangles in the same position, with the right angle located in the same place to explore the ratios of their sides. Such activities remain beneficial, although they are boring and prone to errors when students (Marino et al., 2018). This results in students having difficulty

determining trigonometric ratios when the position of the right angle changes. There has not yet been any research that develops an application aimed at helping students visualize the position of right triangles in various orientations. From a theoretical perspective, this study is grounded in Dual Coding Theory (Paivio, 1986) and Cognitive Load Theory (Sweller, 1994), which emphasize that combining visual and verbal representations can enhance conceptual understanding while reducing cognitive overload. Based on this foundation, the present study aims to develop and evaluate the effectiveness of an interactive visual learning application named AVIGO to assist vocational students in understanding trigonometric ratios through dynamic visualization. The application targets vocational education contexts where trigonometry materials are often limited compared to general secondary schools. Through its dynamic rotation feature, AVIGO is designed to enable students to visualize right triangles in multiple orientations and to measure its impact on their conceptual understanding and learning motivation in trigonometry

METHOD

This research is a development study, employing an integrated R&D framework based on the of Borg & Gall Model (1983) and (Lee & Owens, 2004) multimedia development frame work. Borg and Gall's model provides a systematic sequence for educational product validation and field testing, while Lee and Owens' model offers detailed stages for multimedia content design and learner analysis. The integration of both frameworks allows for a more comprehensive approach, combining the pedagogical rigor of Borg and Gall's cycle with the technological precision of Lee and Owens' stages, resulting in a development process that ensures both instructional quality and usability of the digital product.

The output produced from this research is an innovative product that will be used in high school mathematics education. The developed product is an interactive trigonometry visualization application, which we will henceforth refer to as AVIGO. For the purpose of reproducibility, the application was developed using

the Unity game engine as a native Android application intended for students' smartphones. The application requires a minimum operating system of Android 10 or newer to ensure functionality. The aim of this application is to assist students in enhancing in understanding and solving trigonometric ratio problems (sin, cos, tan). The mathematical material used in this research is the comparison of triangle sides for Class X vocational high school students.

Participants and Data Collection

This research conducted at SMK Kartika IV-1 Malang. The school was selected purposively based on a documented needs analysis (as detailed in the introduction) indicating this research was relevant to the partner's need. rior to implementation, formal permission was obtained from the school principal and classroom teacher. All student participants were informed of the study's objectives and provided informed consent, and all data was anonymized to ensure confidentiality. The subjects of this research include: (1) expert validators in media, selected based on their expertise in educational technology and instructional multimedia design; and materials, selected based on their academic expertise and significant experience in mathematics education; (2) mathematics teachers, selected due to their role as the classroom teacher for the target students and their practical understanding of the students' characteristics; (3) 52 tenth-grade students at SMK Kartika IV-1 Malang. Data sources were obtained directly from the results of expert validation sheets filled out by validators, questionnaire surveys filled out by the involved students and teachers, as well as the results of observations conducted by the researcher during the trial.

The data collection instruments used in this study are product validation sheets and student questionnaires for testing practicality and effectiveness. All about instruments were developed by the research for specific study. The theoretical constructs used to measure product quality were adapted from established frameworks in educational media development, such as the validation approach

used by Qohar et al. (2021) in their development of an Android-based mathematics game.

All items were presented using a 4-point Likert scale (1 = Not Good, 4 = Very Good). The validation sheet contains three aspects: content aspect, alignment with the application usage goals (helping students understand and solve problems), and appearance and language aspect. Following successful expert validation, a small-scale technical trial was conducted. This trial was structured specifically to identify and resolve application bugs (debugging) before the main field test. The trial involved four students from the target population. The purpose of this stage was not to measure practicality or effectiveness, but to ensure technical stability. The students were observed as they interacted with all features of the AVIGO application, and any crashes, glitches, or usability bottlenecks were documented. After minor bugs were identified and resolved, the stable version of the application was approved for the main field test. During the main field test with the 52 students, the student questionnaires were administered after they completed the learning session with AVIGO. These questionnaires were designed to measure the product's practicality and effectiveness.

Procedures

The stages of the Borg & Gall model serve as the framework, with elements of the Lee & Owen model integrated into the phases of information collection, planning, product development, and expert evaluation, emphasizing a more focused approach to the development of interactive multimedia (Jaafar et al., 2022). The framework of this integration consists of 12 stages, that are : (1) Collecting of Research and Information; (2) Planning; (3) Development of Preliminary Form of Product; (4) Expert Evaluation; (5) Revisions Based on Expert Evaluation Results (Revision 1); (6) Preliminary Field Testing; (7) Main Product Revision (Revision 2); (8) Main Field Testing; (9) Operational Product Revision (Revision 3); (10) Operational Field Testing; (11) Final Product Revision (Revision 4); (12)

Dissemination and Implementation. Referring to the framework, this study uses different naming for the steps, although the overall process remains the same. The research stages are presented in Figure 1.

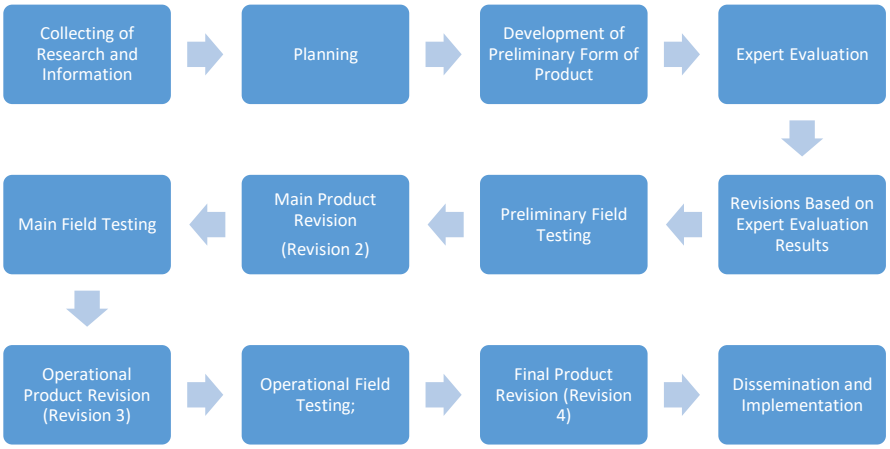

Figure 1. Research Stage of AVIGO

Analysis

The data were analyzed using descriptive statistics. Qualitative data, such as suggestions from validators and comments from students, were used for iterative product revision. Quantitative data from the questionnaires were analyzed to determine the product's level of quality (validity, practicality, and effectiveness). Data analysis technique for validation test questionnaires using the average analysis technique. The validation scores obtained from each validator are averaged, and then the average scores from each validator are used to calculate the overall average. The average validity score obtained is compared. The questionnaire offers four options for each indicator: 1) Very , 2) Inappropriate, 3) Appropriate, and 4) Very Appropriate. From these four options, a validity level table was compiled, as shown in Table 1.

Table 1. Quantitative Data of the AVIGO Validation Test

Average score of validity, practicality, and effectiveness	Criteria of validity, practicality, and effectiveness
$1 \leq V_r / P_r / E_r < 2$	No valid / practical/ effective
$2 \leq V_r / P_r / E_r < 3$	Valid / practical/ effective enough
$3 \leq V_r / P_r / E_r < 4$	Valid / practical/ effective

Average score of validity, practicality, and effectiveness	Criteria of validity, practicality, and effectiveness
$1V_r/\ P_r/E_r = 4$	Very Valid / practical/ effective

Practical and Effectiveness Test, conducting field tests yields practical and effectiveness scores. The results for practicality and effectiveness were obtained from the questionnaires given to the students. The questionnaire offers four answer options for each indicator: 1) Very Inappropriate, 2) Inappropriate, 3) Appropriate, 4) Very Appropriate. The practicality of the product is obtained from each student who participated in the trial, and the average is calculated. The average practicality scores were compared with the practicality level intervals shown in Table 1 to determine the practicality level of the product.

RESULT AND DISCUSSION

a. Validation Test Data

The validation of the application was conducted by two validators: an expert validator, a mathematics lecturer, and a practitioner validator, a mathematics teacher at a vocational school. The validation process yielded both quantitative and qualitative data. The quantitative data comprised mean scores from each validation aspect, which were subsequently averaged to obtain an overall score. Three aspects were evaluated: (1) the content of the application, (2) the materials and visual design of the application, and (3) the construct of the application. The qualitative data consisted of feedback and comments provided by the validators, which were utilized as the basis for revising the developed application. The quantitative results of the validation are presented in Table 2, derived from the questionnaire administered to the validators.

Table 2. Quantitative Data of the AVIGO Validation Test

Aspect Evaluated	Statement	Score
Content	The questions presented in the application align with the trigonometric ratio material for Grade X.	3.5

Aspect Evaluated	Statement	Score
	The questions at each level correspond to the degree of visualization difficulty (Level 1 – standard triangle, Level 2 – non-standard triangle, Level 3 – word problems).	3.5
	The alignment between questions and answers is high.	3.5
Language and Appearance	The language used in the application is clear and easy to understand.	3.5
	The typeface and font size are easy to read.	3.5
	The application display is attractive.	3.5
Construct (Alignment with Objectives)	The application provides opportunities for students to actively engage in understanding the concept of trigonometric ratios.	3.5
	The application facilitates students' understanding of trigonometric ratio concepts.	3.5
	The feature for rotating triangles in the application enhances students' visualization in solving trigonometry problems.	3.5
	The step-by-step presentation of problems in the application supports students in mastering trigonometry material.	3.5
	The step-by-step presentation of problems in the application supports students in mastering trigonometry material.	4.0
	The developed application is expected to increase students' enthusiasm for learning trigonometry.	4.0
	The developed product is expected to enhance students' interest in solving trigonometry problems.	4.0
Overall Validation Score		**3.62**

Based on Table 2, it can be seen that the overall validation score is 3.62, indicating that the developed application falls into the "valid" category as shown in Table 1. Nevertheless, minor revisions were carried out in accordance with the validators' suggestions and comments. The qualitative data are presented in Table 3.

Table 3. Qualitative Data of the AVIGO Validation Test

No.	Suggestions and Comments
1	If there are unanswered items on the application's answer sheet, a message should appear indicating that not all items have been completed.
2	The display of the HINT text should be given a border so that it is clearly visible.
3	The size of the content within the square box should be adjusted appropriately.
4	A home menu needs to be added on each page.

In addition to quantitative validation scores, qualitative feedback was also collected from validators (see Table 3). These comments provided initial insights into the usability and clarity of the application, such as suggestions to add a home menu, improve hint displays, and adjust content layouts. Although these data do not represent a full qualitative study of classroom interactions, they served as valuable input for refining AVIGO before classroom implementation.

b. Application Practicality Data

After the application was declared valid, the next stage was a limited trial. The limited trial was conducted with 4 students and 1 model teacher. The trial was structured as a direct observation session lasting approximately 2 times 45 minutes. During the session, students used their personal smartphone to interact with all features of the AVIGO application under the supervision of the researcher and the teacher. The results showed that no debugging issues occurred during the students' use of the application. This finding was supported by the statement of the model teacher who accompanied the trial process.

The subsequent stage was the broader trial of the application, which had already been validated and shown to be free from debugging issues during the limited trial. The application was tested in three Grade X classes at the vocational school, representing different areas of specialization. Specifically, the trial involved 41 students from the Fashion Design (Tata Busana) department and 11 students from the Cosmetology (Tata Kecantikan) department. These specializations were

chosen to highlight the diverse applicability of trigonometry; concepts which are essential for specific professional tasks in these fields, such as calculating angles for hair cutting (Cosmetology) or designing complex patterns (Fashion Design)..In total, 52 students participated in the product trial. The purpose of this trial was to obtain practicality and effectiveness data. The practicality data were collected from questionnaires completed by the students. The practicality results of the application are presented in Table 4.

Table 4. Practicality Results of AVIGO

Aspect Evaluated	Statement	Score
Practicality	The application's user instructions are clear and easy to understand.	3.21
	The problems (questions) presented are clear and easy to understand.	3.15
	The problems in the application are aligned with the material being studied.	3.17
	The application is easy to use.	3.25
	The language used is appropriate and easy to understand.	3.25
	The typeface and font size are easy to read.	3.31
	The display design is attractive.	3.48
Overall Practicality Score		**3.26**

Based on Table 4, the overall practicality score of the application was 3.26, indicating that the developed application falls into the "practical" category as shown in Table 1. In this context, "practical" means that the application is easy to use for learning trigonometry. Students found the application easy to operate because the instructions were clear and easy to follow. In addition, the application's display was considered attractive, with a score of 3.48, and the typeface and font size were easy to read. The problems/questions in the application were also presented clearly, thereby avoiding ambiguity or confusion among students.

The problems in AVIGO are structured progressively, starting with simple conceptual questions and advancing to more complex application-level problems, intentionally applying the pedagogical principle of 'scaffolding' (Vigotsky, 1978).

This structure is designed to operate within the students' Zone of Proximal Development (ZPD), starting with simple conceptual questions and advancing to more complex application-level problems. This sequencing allows students to gradually master trigonometric concepts according to their abilities. Moreover, for problems involving non-standard triangles, students can rotate the figures to find an orientation that suits their understanding. This interactive feature enriches the learning experience by helping students visualize problems more clearly and engage more actively in problem solving.

c. Application Effectiveness Data

Table 5 presents the effectiveness data obtained from student questionnaires following the trial use of the application. These data reflect the degree to which the application supported students in mastering the topic of trigonometric side ratios in right-angled triangles. Mastery in this context refers to students' ability to understand the underlying concepts and apply them in problem-solving.

Table 5. Effectiveness Results of AVIGO

Aspect Evaluated	Statement	Score
Effectiveness – Mastery of Trigonometry (Understanding Concepts and Solving Problems)	The application provides opportunities for students to actively engage in understanding trigonometric ratio concepts.	3.31
	The application facilitates students' understanding of trigonometric ratio concepts.	3.15
	The feature for rotating triangles in the application helps students visualize and solve trigonometry problems.	3.19
	The step-by-step presentation of problems in the application supports students in mastering (solving problems in) trigonometry material.	3.06
	Students feel happy and more motivated when learning trigonometry using the application.	3.12
Overall Effectiveness Score		**3.22**

Based on Table 5, the overall effectiveness score of the developed application was 3.22. This indicates that the application is considered effective according to Table 1. The application effectively supported students in mastering trigonometry material. Students were actively engaged, felt happy, and were more motivated in the process of understanding trigonometric ratio concepts. This quantitative finding was supported by qualitative data from observations and informal feedback. For example, one student stated: *"This is much easier; I finally understand why the side changes when the triangle rotates*." The model teacher who accompanied the trial process stated to the researcher, "Students were motivated in learning trigonometry and expressed hope for the availability of applications like AVIGO for learning other mathematics topics". Not only that, the model teacher also state, *"Student were not afraid to try the problems because the rotation feature helped them see the solution. I hope this can be used in the future."* This is reflected in the scores of two related statements, both of which were above 2.

In addition to the quantitative scores, qualitative data from student responses also indicated that AVIGO provided a more engaging learning experience. Students reported that the interactive visualization, particularly the feature of rotating right-angled triangles in non-standard orientations, helped them to better understand and solve problems. This interactive element allowed students to adjust the figures according to their perception, thereby reducing confusion and supporting clearer visualization. These findings complement the numerical results and confirm that AVIGO not only improves conceptual understanding but also enriches the overall learning experience.

Technology-oriented classrooms provide a medium that accommodates the teaching and learning of mathematics and the development of mathematical understanding (Bekene Bedada & Machaba, 2022). Such classrooms serve as powerful tools that enhance teaching and learning. According to (NCTM, 2000) teachers are the primary decision-makers in the use of technology in the classroom. The most critical decision lies in determining when technology should be used and

when it should not. Schools, therefore, bear the responsibility of providing appropriate access to technology.

Modern technology offers many opportunities for the teaching and learning process. A variety of tools are currently available for mathematics instruction at different levels of sophistication. Various types of technology can support teachers and students in investigating, generating, creating, and exploring mathematical ideas (Muhammad et al., 2024). AVIGO is an application designed to facilitate students' understanding of right-angled triangles in trigonometry. Mastery of right-angled triangles is fundamental for learning trigonometry (Theses et al., 2019).

AVIGO is designed to give students opportunities to explore right-angled triangles in different orientations. According to Obeng et al. (2024), it is essential for students to be able to identify the sides of a right-angled triangle, then calculate the right angle using the Pythagorean theorem and standard trigonometric ratios such as sine, cosine, and tangent. Students are further introduced to more advanced trigonometric concepts such as the sine and cosine rules, trigonometric identities, compound identities, and their real-world applications. Research by Mensah (2017) shows that process errors, transformation errors, and misconceptions are the most common mistakes students make when applying formulas and right-angled triangles to solve trigonometric ratio problems. With the aid of technology, learning about right-angled triangles is expected to become more effective. This aligns with Riskadewi's (2023) findings that learning right-angled triangles with technological support is effective, as it reduces boredom and disengagement often caused by abstract instruction.

The application was developed with varying levels of problem difficulty low, medium, and high. Adjusting the level of problem difficulty to students' abilities is important in mathematics learning. Rukli & Ma'rup (2022) found that differentiating the level of difficulty in mathematical problems can increase students' interest and motivation. Similarly, Chaudhuri et al. (2022) emphasized the importance of accommodating students' varying abilities in the learning process, as

this influences how teachers provide appropriate support to meet students' individual needs. Providing resources aligned with students' needs enables them to independently develop their skills in understanding and solving problems at their own level of comprehension. The AVIGO application was therefore designed to present problems tailored to students' levels of ability.

AVIGO functions as a learning medium that employs visual representation. Marikyan (2023) highlights that the use of visuals supports the development of analytical thinking skills. Visuals have been shown to effectively promote mathematical thinking, problem-solving, and reasoning. There are clear benefits to incorporating visuals in mathematics learning. The National Council of Teachers of Mathematics (NCTM, 2000)stresses the importance of visualization in mathematics instruction and advocates the use of visuals to help students understand mathematical concepts and relationships. Cognitive load theory also suggests that visuals can reduce cognitive burden. Visual representation can enhance student learning (Placa et al., 2023) Representations are a key component of mathematics instruction, as they enable students to better understand problems. When students learn to represent mathematical ideas, connect them, and build deeper conceptual understanding, they also improve their problem-solving abilities. In mathematics learning, interactive instruction can capture students' attention and foster participation (Hetmanenko, 2024). Interactive learning plays an important role in mathematics education by enhancing student engagement and interest. AVIGO supports active and interactive learning, allowing students to study trigonometry at their own pace and ability. Students are challenged to solve tasks that range from low to high levels of difficulty.

The use of AVIGO is designed to provide students with learning opportunities beyond classroom hours and school settings, enabling them to study anytime and anywhere. Visual media support students in understanding right-angled triangle concepts, while the interactive nature of the application promotes active learning. Thus, AVIGO is expected to motivate students in understanding the relationship

between angles and side lengths in right-angled triangles, thereby mastering trigonometric ratios and ultimately applying trigonometry to real-life contexts.

Although the findings of this study indicate that AVIGO is valid, practical, and effective as a learning medium, several limitations should be acknowledged. First, the trials were limited to classroom implementation within the school schedule, so the long-term impact of AVIGO on students' understanding and motivation could not be measured. Second, while qualitative data such as validator feedback, student responses, and teacher observations were included, the study did not conduct an in-depth qualitative analysis of changes in students' problem-solving strategies. Third, students' motivation was observed through feedback and teacher notes, but not systematically measured in terms of independent learning beyond classroom hours. These limitations highlight the need for future research to conduct long-term trials, deeper qualitative analyses, and more specific investigations into students' intrinsic motivation.

CONCLUSION

Based on the R&D process, it is concluded that the AVIGO application, featuring a dynamic rotation function, has been successfully developed and is declared valid, practical, and effective for teaching trigonometric ratios in vocational high schools. AVIGO is an interactive visual trigonometry application designed to assist students in understanding and solving problems related to trigonometric ratios. AVIGO was developed using Unity software and incorporates concise instructional material on trigonometric ratios presented through videos, right-angled triangle illustrations in both standard and non-standard orientations, as well as real-life problems involving side ratios of triangles.

AVIGO is recommended for use in teaching trigonometric ratio concepts, as it helps students accurately visualize the position of right-angled triangles and, in turn, understand the relationship between angles and side lengths. The application employs visual representations and promotes active learning due to its interactive nature. Compared to other applications such as GeoGebra, which is more general

in scope, or Android-based trigonometry apps that mainly provide materials and practice questions, AVIGO emphasizes interactive visualization and contextual problem solving tailored to vocational students' needs. This distinction highlights AVIGO's contribution as a more focused and accessible tool in trigonometry education.

The implications of this research are twofold. For mathematics education, it provides evidence that interactive visualization tools are crucial for demystifying abstract concepts. For vocational education, this study highlights the role of targeted technology in bridging abstract mathematics with practical, non-technical trades like Fashion Design and Cosmetology.

This study suggests several directions for future research. First, a quasi-experimental study (pre-test/post-test) is recommended to measure quantitative learning gain. Second, the AVIGO framework could be adapted for other visual-spatial concepts (e.g., 3D Geometry, Vectors). Third, the application should be tested with other student populations, such as those in engineering tracks or general high schools.

REFERENCES

Adhikari, T. N., & Subedi, A. (2021). Difficulties of Grade X students in learning Trigonometry. *Siddhajyoti Interdisciplinary Journal*, *2*(01), 90–99. https://doi.org/10.3126/sij.v2i01.39243

Arce Sánchez, M., Pecharromán Gómez, C., Ortega del Rincón, T., & Mwenya Musonda, T. (2023). Designing a Theoretical Proposal Using Problem – Based Learning to Improve Learning of Trigonometric Ratios among Grade Eleven Students. *American Journal of Educational Research*, *11*(2), 53–78. https://doi.org/10.12691/education-11-2-5

Asfar, A. M. I. T., & Asfar, A. M. I. A. (2020). Case-based games learning strategies to improve conceptual understanding in mathematics. *Journal of Physics: Conference Series*, *1663*(1). https://doi.org/10.1088/1742-6596/1663/1/012060

Asmianto, Hafiizh, M., Rahmadani, D., Pusawidjayanti, K., & Wahyuningsih, S. (2022). Developing Android-Based Interactive E-Modules on Trigonometry to Enhance the Learning Motivation of Students. *International Journal of Interactive Mobile Technologies*, *16*(2), 159–170. https://doi.org/10.3991/ijim.v16i02.27503

Asomah, R. K., Agyei, D. D., Ntow, F. D., & Benning, I. (2023). Hypothetical Approach to the Teaching of Trigonometric Concepts Using Cooperative Learning. *Education Research International*, *2023*. https://doi.org/10.1155/2023/2051776

Bekene Bedada, T., & Machaba, F. (2022). The effect of GeoGebra on STEM students learning trigonometric functions. *Cogent Education*, *9*(1), 1–18. https://doi.org/10.1080/2331186X.2022.2034240

Chaudhuri, S., Muhonen, H., Pakarinen, E., & Lerkkanen, M. K. (2022). Teachers' visual focus of attention in relation to students' basic academic skills and teachers' individual support for students: An eye-tracking study. *Learning and Individual Differences*, *98*(July), 102179. https://doi.org/10.1016/j.lindif.2022.102179

Defi, S. L., & Qohar, A. (2022). *Development of learning media based on Geogebra software on the topic of trigonometric ratios*. 020002. https://doi.org/10.1063/5.0099631

Ernaningsih, Z., & Wicasari, B. (2017). Analysis of mathematical representation , communication and connection in trigonometry. *The 2017 International Conference on Research in Education*, 45–57.

Hetmanenko, L. (2024). The role of interactive learning in mathematics education: Fostering student engagement and interest. *Multidisciplinary Science Journal*, *6*(May). https://doi.org/10.31893/multiscience.2024ss0733

Hidayat, W., Rohaeti, E. E., Hamidah, I., & Putri, R. I. I. (2023). How can android-based trigonometry learning improve the math learning process? *Frontiers in Education*, *7*(January), 1–13. https://doi.org/10.3389/feduc.2022.1101161

Jaafar, N. A., Rohani, S., Nor, M., Norrulashikin, S. M., Arina, N., & Kamisan, B. (2022). Increase Students ' Understanding of Mathematics Learning Using the Technology-Based Learning. *International Journal of Advanced Research in Future Ready Learning and Education*, *1*(1), 24–29. https://www.akademiabaru.com/submit/index.php/frle/index

Joshi, R. R. (2022). *Students' Achievement in Trigonometry Teaching Through Geogebra*.

Kgaladi, M., Paul, M., & Elizabeth, P. (2023). Exploring Grade 11 Learners' Mathematical Connections When Solving Trigonometric Equations. *Symmetry: Pasundan Journal of Research in Mathematics Learning and Education*, *8*(1), 81–94.

Lee, W. W., & Owens, D. L. (2004). *Multimedia-based Instructional Design*. Pfeiffer.

Marikyan, G. (2023). Teaching Mathematics with Visuals Gohar Marikyan. *Athens Journal of Sciences*, *10*(4), 231–240. https://doi.org/10.30958/ajs.10-4-3

Marino, M. T., Israel, M., Vasquez, E., Fisher, K. M., & Gallegos, B. (2018). Teaching and learning with technology. *The Wiley Handbook of Educational Foundations*, *January 2010*, 245–260. https://doi.org/10.1002/9781118931837.ch15

McLaren, B. M., Richey, J. E., Nguyen, H., & Hou, X. (2022). How instructional context can impact learning with educational technology: Lessons from a study with a digital learning game. *Computers and Education*, *178*(August 2021), 104366. https://doi.org/10.1016/j.compedu.2021.104366

Mensah, F. S. (2017). Ghanaian Senior High School Students' Error in Learning of Trigonometry. *International Journal Of Environmental & Science Education*, *12*(8), 1709–1717.

Mosese, N., & Ogbonnaya, U. I. (2021). GeoGebra and students' learning achievement in trigonometric functions graphs representations and interpretations. *Cypriot Journal of Educational Sciences*, *16*(2), 827–846. https://doi.org/10.18844/CJES.V16I2.5685

Muhammad, G. A., Adamu, A., & Zubair, S. I. (2024). Teaching and Learning Trigonometry with the Technology of Graphing Calculator: Making the Teacher Competent. *International Journal of Education and Evaluation*, *10*(2), 89–99. https://doi.org/10.56201/ijee.v10.no2.2024.pg89.99

Nanmumpuni, H. P., & Retnawati, H. (2021). Analysis of Senior High School Student's Difficulty in Resolving Trigonometry Conceptual Problems. *Journal of Physics: Conference Series*, *1776*(1). https://doi.org/10.1088/1742-6596/1776/1/012012

NCTM. (2000). *Principles and Standards for School Mathematics*. VA NCTM.

Nurmeidina, R., & Rafidiyah, D. (2019). *Analysis of Students' Difficulties in Solving Trigonometry Problems*. https://doi.org/10.4108/eai.7-8-2019.2288422

Obeng, B. A., Banson, G. M., Owusu, E., & Owusu, R. (2024). Analysis of senior high school students' errors in solving trigonometry. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2385119

Phonapichat, P., Wongwanich, S., & Sujiva, S. (2014). An Analysis of Elementary School Students' Difficulties in Mathematical Problem Solving. *Procedia - Social and Behavioral Sciences*, *116*(2012), 3169–3174. https://doi.org/10.1016/j.sbspro.2014.01.728

Placa, N., Koellner, K., & Seago, N. (2023). *VISUAL REPRESENTATIONS AS A SUPPORT FOR SUSTAINED TEACHER LEARNING*. 1178–1181. https://doi.org/10.21125/iceri.2023.0393

Qohar, A., Susiswo, Nasution, S. H., & Wahyuningsih, S. (2021). Development of Android-Based Mathematics Learning Game on the Topic of Congruence and Similarity. *International Journal of Interactive Mobile Technologies*, *15*(9), 52–69. https://doi.org/10.3991/ijim.v15i09.20723

Rebollo, C., Remolar, I., Rossano, V., & Lanzilotti, R. (2022). Multimedia augmented reality game for learning math. *Multimedia Tools and Applications*, *81*(11), 14851–14868.

Riskadewi, K. N. (2023). Integrating Problem-Solving Skills in Developing Trigonometric Ratio Learning Videos for Right-Angled Triangles. *Jurnal Praktik Baik Pembelajaran Sekolah Dan Pesantren*, *2*(02), 80–87. https://doi.org/10.56741/pbpsp.v2i02.365

Rukli, R., & Ma'rup, M. (2022). The Impact of Students Assessing the Level of Difficulty Test Item on Interest and Motivation in Learning Mathematics. *Randwick International of Education and Linguistics Science Journal*, *3*(2), 229–240. https://doi.org/10.47175/rielsj.v3i2.476

Sarac, A., & Aslan Tutak, F. (2017). The Relationship between Teacher Efficacy, and Students' Trigonometry Self-Efficacy and Achievement. *International Journal for Mathematics Teaching and Learning*, *18*(1), 66–83. https://doi.org/10.4256/ijmtl.v18i1.41

Theses, U., Papers, P., Artifacts, C., & Dereu, E. (2019). *ScholarWorks at University of Montana Student ' s Self Discovery of Right Triangle Trigonometry . Let us know how access to this document benefits you .*

Vigotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Walter R Borg, & Joyce P Gall. (1983). *Educational research: An introduction*. New York Longman.

Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. *International Journal of STEM Education*, *9*(1). https://doi.org/10.1186/s40594-022-00344-0

Zaneta, V. (2022). Media Game Online Ular Tangga Perkalian Bilangan Asli Dengan Pendekatan RME Kelas III SD. *Plusminus: Jurnal Pendidikan Matematika*, *2*(2), 177–186. https://doi.org/10.31980/plusminus.v2i2.1819