



The Development of a STEAM-Based Smart Math Application for Interactive and Enjoyable Mathematics Learning in the Digital Era

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ABSTRACT

Purpose of the study: This study aims to develop the STEAM-based Smart Math App as an innovative, interactive, and enjoyable mathematics learning tool to enhance students' motivation and learning outcomes in the digital era.

Methodology: The study used the 4D development model (Define, Design, Develop, Disseminate) to create and validate the application. The software Flip PDF Professional was used to develop the app, and it was tested on 32 students of class XI.2 at MAN 1 Soppeng. The study also involved expert validation for content and media aspects.

Main Findings: The pretest score averaged 61.25 (low), while the posttest score increased to 83.16 (high). Students' responses to the app were highly positive, with an average score of 3.45. The application significantly improved student engagement and learning outcomes.

Novelty/Originality of this study: The STEAM-based Smart Math App integrates multimedia and interactive elements for mathematics learning, offering a fresh approach to overcoming traditional learning challenges. This study contributes to the advancement of educational technology, improving mathematics learning by integrating STEAM principles for a more engaging and effective learning experience.

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1. INTRODUCTION

Education is an essential foundation for shaping a well-rounded individual, encompassing the development of cognitive, affective, and psychomotor aspects of students. As a systematically planned process, education aims not only to transfer knowledge but also to form attitudes, morals, and skills required for societal life [1]. According to the National Education System Law No. 20 of 2003, education is intended to create a learning environment that allows individuals to develop their potential in various aspects, including spiritual strength, self-control, and intellectual and emotional intelligence. In this context, mathematics plays a very important role. Mathematics not only serves as a tool for problem-solving and analyzing situations but also as a means to develop logical, systematic, and creative thinking skills that are essential for individuals in daily life [2];[3]. Mathematics helps individuals develop critical and analytical thinking abilities required in many fields, including science, technology, economics, and engineering[4];[5]. However, despite the importance of mathematics in fostering critical thinking, many students find this subject difficult and unappealing[5];[6]. This presents a major challenge in education, particularly in mathematics learning, which is often considered difficult and boring.

Mathematics learning requires high levels of reasoning due to its connection with abstract concepts. As a result, understanding mathematics requires perseverance, focus, and strong motivation from students. However, in reality, many students struggle to understand abstract mathematical concepts, especially when taught monotonously or in a non-contextual manner[7]; [8]. This can lead to decreased student motivation, resulting in poor mathematics performance. According to PISA (Programme for International Student Assessment) data released by the OECD in 2022, Indonesia ranked 70th out of 81 countries in mathematical literacy, with an average score of only 366 [9]. In contrast, Singapore ranked first with a score of 575. This data reflects the low mathematical proficiency of Indonesian students, with around 82% of students failing to achieve basic mathematical competency.

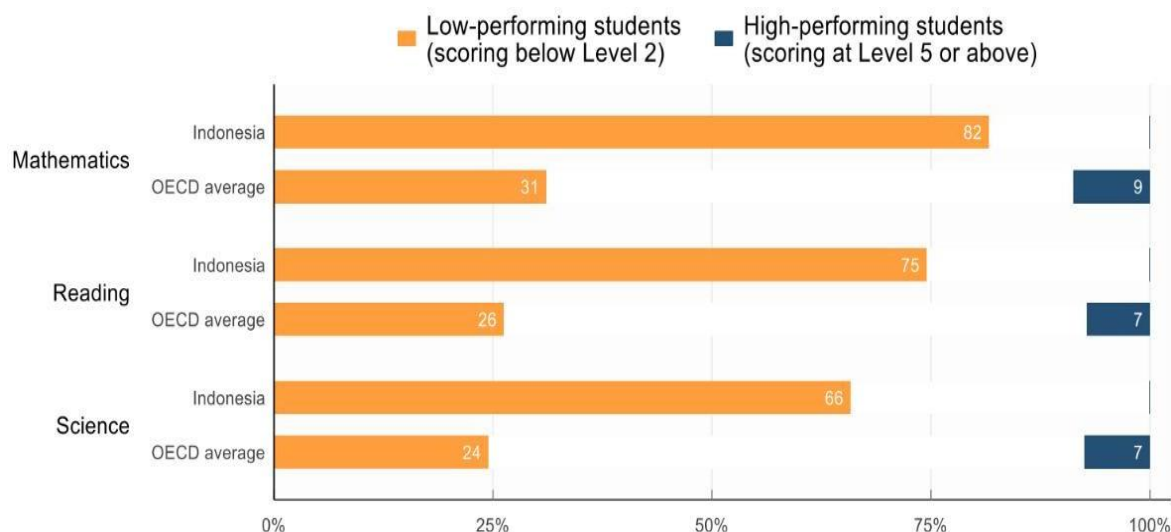


Figure 1. Percentage of Indonesian Students' Math Performance

A similar phenomenon was also observed at MAN 1 Soppeng, where initial observations revealed that most students had not met the Minimum Completeness Criteria (KKM) for mathematics. The average score of class XI students was 58.6, while the KKM was set at 72. Additionally, students showed a lack of active participation in the learning process, indicating problems with the teaching methods used. Based on these findings, it was determined that monotonous and non-interactive teaching methods were one of the reasons for students' poor understanding of the material being taught. To address this issue, one solution that can be applied is to develop a technology-based mathematics learning application that is engaging and interactive [10]. For example, the Smart Math Apps application, developed using Flip PDF Professional software, can serve as an innovative alternative to improve the quality of mathematics learning. This application allows for the creation of more dynamic mathematics learning materials by adding various interactive media elements, such as videos, images, audio, animations, and hyperlinks. By utilizing this technology, mathematics learning can be delivered in a more engaging, enjoyable, and flexible way, which can increase students' motivation to learn.

However, in addition to interactivity and the diversity of learning media, it is important to integrate a more holistic approach to mathematics learning. One approach that can be applied is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach [11];. The STEAM approach integrates five distinct disciplines—science, technology, engineering, arts, and mathematics—into one interconnected learning experience [12]; [13]. This approach provides an opportunity to develop students' skills more comprehensively, emphasizing creativity, collaboration, and the practical application of mathematical concepts in everyday life [13]. Applying the STEAM approach to mathematics learning can help students not only understand mathematical theories deeply but also apply their mathematical knowledge in broader contexts, such as in projects involving technology and the arts [14]; [15]. For instance, in the development of the STEAM-based Smart Math Apps application, students can learn not only mathematical concepts but also how to use technology and the arts to create engaging

and interactive learning media. In this way, mathematics learning becomes more contextual and relevant to the needs of the times, as well as more enjoyable and challenging for students [16]; [17]; [18].

The development of a STEAM-based Smart Math application is an important innovation in the field of education, particularly in mathematics learning. One of the aspects that distinguish this application from conventional teaching methods is the integration of five disciplines into a comprehensive learning package. This application allows students to understand mathematics not just as numbers and formulas, but as a tool for solving real-world problems involving various fields. Through the STEAM approach, this application can provide a more holistic and enjoyable learning experience, where students are encouraged to explore their creativity, solve problems innovatively, and collaborate. The urgency of developing this application is also clear, given the low level of mathematical understanding among students in Indonesia, as reflected in the PISA results. By integrating digital technology and the STEAM approach, this application can provide a solution to improve students' motivation and understanding of mathematics. This application not only offers an interactive and enjoyable learning experience but also helps students develop essential skills in the digital era, such as critical thinking, creativity, and collaboration.

Furthermore, the development of this application is also relevant to the need for digital transformation in education. In this digital era, learning is no longer limited to traditional classroom settings; it can take place anytime and anywhere using digital devices. Therefore, the STEAM-based Smart Math application is expected to be an effective alternative in overcoming the limitations of educational access and improving the quality of mathematics learning across Indonesia. Thus, the development of this application is not only an innovation in mathematics learning but also an effort to advance education in Indonesia in the digital era.

2. RESEARCH METHOD

The type of research used is development research (R & D). According to Borg and Gall, Educational Research and Development (R&D) is a process used to develop and validate educational products [19]. The development of educational products/teaching devices requires development models that are appropriate for the education system. In this case, the product being developed by the researcher is an application called the Smart Math Application based on STEAM, which serves as an interactive and enjoyable mathematics learning media in the digital era. The development model used is the 4D (Four-D) model, which consists of four stages: define, design, develop, and disseminate [20].



Figure 2. Stages of the 4D Development Model

Table 1. 4D Description

Stages	Discription
Difine	This stage explains the requirements and collects information related to the things that will be developed in the product to be created. This stage includes initial-final analysis, learner analysis, task analysis, concept analysis, and specific instructional objectives.
Design	At this stage, media selection, format selection, and initial design can be carried out.
Develop	At this stage, researchers create products according to the designs that have been made, which are then validated by experts and tested on students.
Disseminate	At this stage, the product can be distributed to the wider community beyond the scope of development itself

The research was conducted at MAN 1 Soppeng, located at Jalan Kayangan No. 162 Soppeng, South Sulawesi. The test subjects consisted of 32 students from class XI.2 and two experts (subject matter expert and media expert) for expert validation. The data collection techniques used were observation, learning outcome tests, student response questionnaires, and interviews. The instruments used in this study were a test of understanding of mathematics material (Trigonometry) and student

responses to the application of STEAM-based Smart Math Apps. The test comprehension and student response data were analyzed quantitatively, while data in the form of criticism, suggestions, and responses from students and experts regarding STEAM-based Smart Math Apps were analyzed qualitatively.

3. RESULTS AND DISCUSSION

The results and discussion were obtained based on inventions during the research and development process using the Four-D (4D) model. This article focuses on describing the process or steps in the 4-D model (define, design, develop, and disseminate) used for the development of STEAM-based Smart Math Apps media.

Result

3.1. Define

The needs analysis stage is the foundation for the development of learning tools, particularly mathematics learning media for trigonometry material at MAN 1 Soppeng. This stage involves gathering information and determining the crucial needs for the next development steps. Based on interviews with mathematics teachers, data was obtained that the lecture and discussion methods predominantly used in learning were still ineffective for complex trigonometry learning, resulting in low student understanding and motivation. Learning resources such as books and worksheets were still limited, with the internet becoming an important alternative, although students' digital literacy needed to be improved. The use of PowerPoint as the main learning medium is not interactive enough, so variety is needed to avoid boredom. The majority of students have smartphones and internet access, but they do not make optimal use of them for learning. Facilities such as computer labs, Smart TVs, and LCDs have limited access, even though free Wi-Fi is available and supports learning. These findings indicate the need to optimize the use of technology as a learning medium and to develop students' digital literacy.

Based on student analysis, many 11th grade students have not mastered the basic concepts of trigonometry, which has an impact on their low learning achievement. Therefore, this study focuses on the development of STEAM-based Smart Math to support mathematics learning, especially trigonometry. This application is designed to facilitate access to material, offer interactive and attractive features, and is expected to be an innovative solution that improves understanding and motivation to learn. The concept analysis ensures the identification of in-depth trigonometry competencies, including understanding definitions, formulas, and their applications, as well as their relationship with other mathematical concepts to develop systematic learning.

3.2. Design

At this stage, the design process begins with the selection of media, format, and product design. The media developed in this study is STEAM-based Smart Math Apps for trigonometry material. This application utilizes images, audio, video, and simulations to explain trigonometry concepts in a more visual and dynamic way, which can make it easier for students to understand material that is sometimes considered abstract. The selection of learning formats is crucial to achieving the desired objectives, including strategies, approaches, methods, and learning resources. This study applies the Discovery Learning model, which encourages active knowledge discovery through exploration, supported by group discussion, assignments, question and answer sessions, and presentations to enhance interaction and collaboration. The media used include interactive applications (videos, images, quizzes, online forums), Student Worksheets (LKPD), and Quizizz, all of which can be accessed flexibly via computers or smartphones. The learning resources used refer to the independent curriculum, including student and teacher handbooks, with the hope that the combination of these media and resources can improve comprehensive understanding and critical and creative thinking skills, so that mathematics learning becomes more interactive, flexible, effective, and meaningful.

In the initial design stage of the application, the researcher identified and organized all the information to be presented in the application. This includes collecting materials, developing text, images, videos, and other multimedia elements relevant to the purpose of the application. The content must be developed with the target audience in mind, so that the material presented is not only informative

but also interesting and easy to understand. The initial design of the application includes a home page, main menu, application instructions, attendance, learning objectives, materials, sample questions, literacy, quizzes, and a question section.

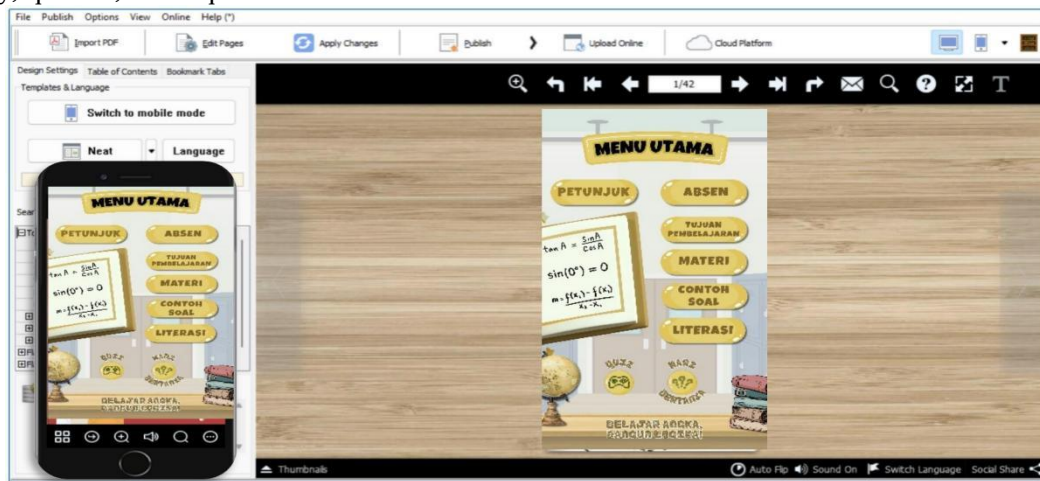


Figure 3. STEAM-based Smart Math Apps design

3.3. Develop

The develop stage in the 4-D development model is the stage where learning media is developed or created based on the design that has been prepared in the previous stage. At this stage, it begins with the creation of an application in table 2 below:

Table 2. Application creation process

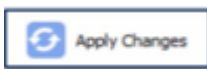
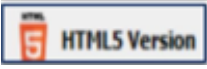
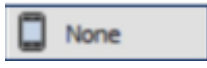
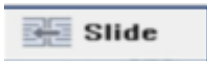
Applications	Description
 Import PDF	Import PDF is used to import PDF files that have been created into the application
 Edit Pages	Edit Pages is used to edit or design the appearance of the book by editing the pages according to the desired appearance.
 Apply Changes	Apply Changes is used to change the file format according to user preferences.
 HTML5 Version	HTML5 Version is used to convert or present digital book files in a responsive, interactive, and compatible manner.
 Flip	Flip is used to change the appearance of text in digital books in terms of position, direction, and presentation style.
 None	None is used to convert digital books to the Android version.
 Slide	A slide that functions to select the desired appearance or shape of a slide in a digital book
 Upload Online	Upload Online is used to publish edited documents or data.



Figure 4. Smart Math Apps based on STEAM

The STEAM-based Smart Math Application offers a variety of interactive features for learning trigonometry. The cover page is attractively designed with the title, relevant images, author's name, and a “start” icon to motivate users. The Main Menu serves as a comprehensive navigation center, providing access to the User Guide. The Guide feature provides complete and structured guidance for users, both teachers and students, to optimally utilize the application in learning trigonometry in grade XI. The attendance feature records student attendance with the options “present, sick, permission”. The learning objectives feature guides students on the competencies to be achieved. The Material feature presents trigonometry concepts in depth with application examples and visualizations. The Example Questions feature presents various practical questions that not only test basic trigonometry concepts (such as sine, cosine, and tangent) but also relate them to applications in everyday life. The literacy feature contains reading materials and supporting videos. The quiz serves as a tool for evaluating understanding with questions and instant feedback, supporting active learning and collaboration. The ask a question feature facilitates communication with teachers or friends through various platforms, creating a supportive learning environment. After the application was created, it was then validated by experts, both subject matter experts and media experts.

a. Subject Matter Expert Validation Results

The trigonometry material in STEAM-based Smart Math Apps was assessed by subject matter experts to determine the suitability of the trigonometry material created in the application. There were two aspects that were assessed, namely the learning design aspect and the linguistic aspect. The following are the results of the assessment of trigonometry comparison material by subject matter experts:

Table 3. Expert material test results

No	Assessment Aspect	Assessment Score	Percentage (%)	Category
1	Learning Design	31	86,11	Valid
2	Language	10	83,33	Valid
Average			84,72	Valid

There are nine statements used to assess the learning design aspects in the STEAM-based Smart Math Apps application. From the analysis, a total score of 29 was obtained, which is equivalent to a percentage of 86.11%. This result shows that the learning design in the application is valid. The

feasibility of the linguistic aspect was assessed based on three statements, and the evaluation results showed a total score of 10, which is equivalent to a percentage of 83.33% and is valid. Based on the results of the learning design and linguistic aspects, it can be concluded that the average assessment of subject matter experts is 84.72%, which is valid.

b. Media Expert Validation Results

Media assessment was conducted to determine the feasibility of the appearance and performance of the trigonometry comparison material application that was developed. There were two aspects that were assessed, namely the software engineering aspect and the visual communication aspect. The following are the results of the media expert assessment that has been carried out:

Table 4. Media Expert Validation Results

No	Assessment Aspect	Assessment Score	Percentage (%)	Category
1	Software Engineering	24	85,71	Valid
2	Visual Communication	32	88,89	Valid
	Average		87,3	Valid

There are seven statements assessed in the software engineering aspect for the application, with a total score of 24 and a percentage of 85.71%. The software engineering aspect of this application is classified as valid. There are nine statements in the visual communication aspect, with an average score of 32 and a percentage of 88.89%, which is classified as valid. Based on the results of the software engineering and visual communication aspects, it can be concluded that the average assessment of subject matter experts is 87.3%, which is in the valid category.

c. Application Trial Results

The results of subject matter experts and media experts in the valid category indicate that STEAM-based Smart Math Apps can be trialed on students. The application was tested on 32 students in class XI.2. To see the effectiveness of the application, a pretest was conducted, followed by treatment (providing material using the application), and then a final test.

The pretest was conducted to determine the students' abilities before implementing the STEAM-based Smart Math Apps. Students were given 15 multiple-choice questions in the pretest. The average result of the students' pretest was 61.25, which is categorized as low. This was followed by the treatment or application of the STEAM-based Smart Math Apps in the learning process for trigonometry material. After being given the treatment with the application, the students took a posttest or final test to determine the effect of using the STEAM-based Smart Math Apps. The posttest results showed an average of 83.16, which is categorized as high.

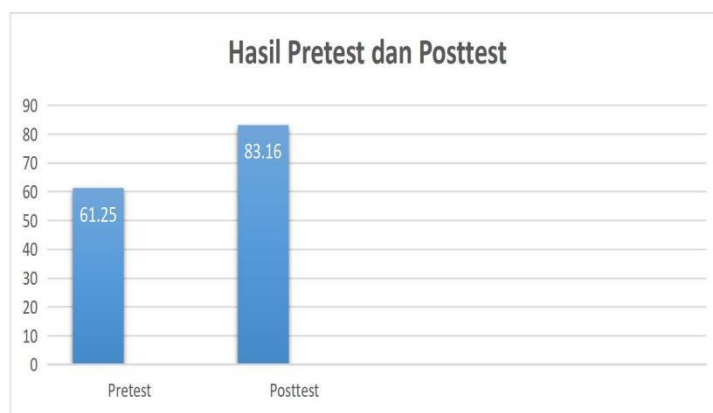


Figure 7. Diagram of Pretest and Posttest results

Student mathematics learning based on Figure 7 shows that the pretest results of students with an average of 61.25 were in the low category, but increased after the application of Smart Math Apps, with a posttest average of 83.16 in the high category. From these results, it can be concluded that the application of Smart Math Apps is very effective in teaching trigonometry.

d. Student Response

In the trial of STEAM-based Smart Math Apps learning media, 32 students responded to 15 statements measuring their responses. The trial results showed an average score of 3.45. This figure, well above the threshold value of 2.5, indicates that student responses to Smart Math Apps were very positive. The closer the score is to 4, the more positive the response, indicating that this learning innovation was very well received by students.

This positive response reflects that the use of STEAM-based Smart Math Apps has succeeded in making all students feel that the material is easier to understand, more interesting, and enjoyable to learn. This confirms the effectiveness of STEAM-based Smart Math Apps as an innovative medium that can increase student engagement and motivation to learn, while also facilitating the process of understanding mathematical concepts that were previously considered difficult.

Discussion

The development of the STEAM-based Smart Math Application for mathematics learning, specifically trigonometry, using the 4D development model (define, design, develop, disseminate) is an innovative step in addressing the challenges of mathematics education in Indonesia. Several studies, such as those by [16]; [17] emphasize the importance of integrating STEAM into learning media to enhance student engagement and understanding. STEAM, which combines Science, Technology, Engineering, Arts, and Mathematics, provides a multidisciplinary approach that facilitates the development of critical thinking, creativity, and collaboration skills in students [21]; [22]; [23]; [24]. In this context, the developed application aims to make mathematics material more interactive and enjoyable through the use of media such as videos, images, and simulations, designed to help students better understand complex trigonometric concepts in a visual and dynamic way [11]; [15]; [16].

The research conducted at MAN 1 Soppeng shows that the implementation of the STEAM-based Smart Math Application successfully increased student motivation and understanding of trigonometry material. Based on the trial results, the application not only improved student performance in pretest and posttest but also received positive responses from students regarding the interactivity and effectiveness of the application. By integrating technology and the STEAM approach, this application provides a more flexible, creative, and relevant learning experience in line with the demands of the digital age [25]; [26]; [27]. The findings of this study highlight the importance of developing technology-based learning media that supports mathematics education in the digital era [28]; [29]; [30] as also found in studies by [11]; [15], which stress the benefits of the STEAM approach in improving the quality of learning at various educational levels.

4. CONCLUSION

The development of the STEAM-based Smart Math Application for mathematics learning, specifically trigonometry, has proven to be effective in enhancing students' understanding and motivation at MAN 1 Soppeng. By applying the 4D development model this application has successfully addressed the challenges in mathematics learning, which is often perceived as abstract and boring by students. The integration of the STEAM approach in this application provides a more interactive and enjoyable learning experience, while helping students relate mathematical concepts to real-life situations. The trial results show a significant improvement in student performance, as well as positive feedback regarding the effectiveness and interactivity of the application. Therefore, this application serves as an innovative solution to improve the quality of mathematics education in the digital era.

Based on the results of this study, it is recommended that the development of the STEAM-based Smart Math Application be expanded and applied in other schools with adjustments to the relevant curriculum. Additionally, further training for educators should be conducted to ensure the optimal use

of this application in teaching. Further research is also needed to test the effectiveness of this application in broader mathematics learning contexts and explore the potential integration of STEAM in other subjects. The development of this application could also include new, varied, and more in-depth features to enhance the quality of learning and provide a more holistic and comprehensive educational experience.

REFERENCES

- [1] S. Satriani, "The Application Of Collaborative Learning Model To Improve Student's 4cs Skills.," *Anatol. J. Educ.*, Vol. 7, No. 1, Pp. 93–102, 2022, Doi: <https://doi.org/10.29333/Aje.2022.718a>.
- [2] J. Nilimaa, "New Examination Approach For Real-World Creativity And Problem-Solving Skills In Mathematics," *Trends High. Educ.*, Vol. 2, No. 3, Pp. 477–495, 2023, Doi: <https://doi.org/10.3390/Higheredu2030028>.
- [3] H. Kurniawan, P. B. Darmono, M. Mursalin, Y. Shang, R. Weinhandl, And R. Sharm, "Describe Mathematical Creative Thinking Skills And Problem-Solving Strategies By Prospective Teacher Students On Non-Routine Problems," *Int. J. Trends Math. Educ. Res.*, Vol. 5, No. 2, Pp. 119–124, 2022, Doi: <https://doi.org/10.33122/Ijtmer.V5i2.140>.
- [4] S. Pahmi, D. Juandi, And R. Sugiarni, "The Effect Of Steam In Mathematics Learning On 21st Century Skills: A Systematic Literature Reviews," *Prisma*, Vol. 11, No. 1, Pp. 93–104, 2022, Doi: <https://doi.org/10.35194/Jp.V11i1.2039>.
- [5] A. H. Prasadi, W. Wiyanto, And E. Suharini, "The Implementation Of Student Worksheet Based On Stem (Science, Technology, Engineering, Mathematics) And Local Wisdom To Improve Of Critical Thinking Ability Of Fourth Grade Students," *J. Prim. Educ.*, Vol. 9, No. 3, Pp. 227–237, 2020.
- [6] M. I. Stanikzai, "Critical Thinking, Collaboration, Creativity And Communication Skills Among School Students: A Review Paper," *Eur. J. Theor. Appl. Sci.*, Vol. 1, No. 5, Pp. 441–453, 2023.
- [7] A. T. Ferede, M. A. Ayele, A. A. Mihrka, And A. A. Arara, "The Impact Of Contextualized Teaching And Learning Approach On Students' Conceptual Understanding Of Trigonometry," *Teach. Math. Its Appl. An Int. J. Ima*, P. Hraf008, 2025, Doi: <https://doi.org/10.1093/Teamat/Hraf008>.
- [8] S. Satriani, W. Uddin, N. H. Halim, And A. Syamsuadi, "The Analysis Of Compliance Type Students Error In Resolving Integral Challenge Of Trigonometry Function," *Int. J. Math. Trends Technol.*, Vol. 66, No. 10, Pp. 14–19, 2020, Doi: [10.14445/22315373/Ijmtt-V66i10p503](https://doi.org/10.14445/22315373/Ijmtt-V66i10p503).
- [9] A. I. Latifah And K. Kismiantini, "How School Culture And Climate Mediated Student's Mathematics Achievement: A Path Analysis Of Pisa 2022 Indonesia Data," *J. Pendidik. Progresif*, Vol. 15, No. 3, Pp. 1670–1687, 2025, Doi: <https://doi.org/10.23960/Jpp.V15i3.Pp1670-1687>.
- [10] J. C. Cronje, "Designing Questions For Research Design And Design Research In E-Learning," *Electron. J. E-Learning*, Vol. 18, No. 1, Pp. 13–24, Jan. 2020, Doi: [10.34190/Ejel.20.18.1.002](https://doi.org/10.34190/Ejel.20.18.1.002).
- [11] W. R. S. P. Mulder, N. Khoiri, And M. S. Hayat, "Analysis Of The Characteristics Of The Development Of Web-Based Science Learning Media With The Steam Approach," *J. Penelit. Pendidik. Ipa*, Vol. 9, No. 11, Pp. 9586–9592, 2023, Doi: [10.29303/Jppipa.V9i11.5095](https://doi.org/10.29303/Jppipa.V9i11.5095).
- [12] N. H. A. Ulya, N. Ishartono, R. B. A. Razak, S. H. B. Halili, M. Khomeini, And L. Mubarakah, "Integration Of Steam-Based Video With Timestamp To Improve Student's Understanding Of Geometric Transformation," In *Aip Conference Proceedings*, 2025, Vol. 3142, No. 1, P. 20060.

- [13] N.-H. Tran, C.-F. Huang, And J.-F. Hung, "Exploring The Effectiveness Of Steam-Based Courses On Junior High School Students' Scientific Creativity," In *Frontiers In Education*, 2021, Vol. 6, P. 666792, Doi: 10.3389/Feduc.2021.666792.
- [14] A. Breda, A. Neves, J. Dos Santos, And Z. Lavicza, "Utilising A Steam-Based Approach To Support Calculus Students' Positive Attitudes Towards Mathematics And Enhance Their Learning Outcomes," *Open Educ. Stud.*, Vol. 5, No. 1, P. 20220210, 2023.
- [15] L. K. Qomatfian, N. Ngazizah, And R. R. Pangestika, "Development Of Steam Learning Media-Based On Coding Scratch Game On The Material Of The Characteristics Of Living Things For Elementary School," *Dwija Cendekia J. Ris. Pedagog.*, Vol. 8, No. 2, Pp. 339–355, 2024, Doi: <https://doi.org/10.20961/Jdc.V8i2.90168>.
- [16] N. Aini, H. Hadiyanto, And A. Widowati, "Development Of Steam-Based Learning Media (Steambook) For Teaching Ecosystem Concepts To Fifth-Grade Elementary Students," *J. Innov. Res. Prim. Educ.*, Vol. 4, No. 4, Pp. 2981–2991, 2025, Doi: <https://doi.org/10.56916/Jirpe.V4i4.2436>.
- [17] I. R. W. Atmojo, R. Ardiansyah, D. Y. Saputri, And F. P. Adi, "The Effectiveness Of Steam-Based Augmented Reality Media In Improving The Quality Of Natural Science Learning In Elementary School," *Al-Ishlah J. Pendidik.*, Vol. 13, No. 2, Pp. 821–828, 2021, Doi: 10.35445/Alishlah.V13i2.643.
- [18] E. Sukmawati, N. D. N. Imanah, And D. A. Rantauni, "Implementation And Challenges Of Project-Based Learning Of Steam In The University During The Pandemic: A Systematic Literature Review," *Jinop (Jurnal Inov. Pembelajaran)*, Vol. 9, No. 1, Pp. 128–139, 2023, Doi: <https://doi.org/10.22219/Jinop.V9i1.25177>.
- [19] T. Siregar, "Stages Of Research And Development Model Research And Development (R&D)," *Dirosat J. Educ. Soc. Sci. Humanit.*, Vol. 1, No. 4, Pp. 142–158, 2023.
- [20] R. B. Indaryanti, H. Harsono, S. Utama, B. Murtiyasa, And B. Soemardjoko, "4d Research And Development Model: Trends, Challenges, And Opportunities Review," *J. Kaji. Ilm.*, Vol. 25, No. 1, Pp. 91–98, 2025, Doi: <https://doi.org/10.31599/Na7deq07>.
- [21] D. Apriandi, I. Krisdiana, E. Suprpto, And B. A. Megantara, "Development And Effectiveness Of Steam-C Integrated Learning Devices To Improve Students' Creative Thinking Skills In Specific Cultural Context.," *J. Learn. Dev.*, Vol. 10, No. 3, Pp. 440–451, 2023.
- [22] E. O. Babalola And E. Keku, "Ethno-Stem Integrated Project-Based Learning To Improve Students' Creative Thinking Skills," *Int. J. Ethnoscience Technol. Educ.*, Vol. 1, No. 2, Pp. 116–130, 2024.
- [23] E. S. Utaminingsih And E. Ellianawati, "Development Of Steam-Based E-Modules On Human Circulatory Topics Containing Critical Reasoning And Independent Characters," *Turkish Online J. Distance Educ.*, Vol. 26, No. 1, Pp. 48–84, 2025, Doi: <https://doi.org/10.17718/Tojde.1368962>.
- [24] R. D. Kurniati, D. Andra, And I. W. Distrik, "E-Module Development Based On Pbl Integrated Stem Assisted By Social Media To Improve Critical Thinking Skill: A Preliminary Study," In *Journal Of Physics: Conference Series*, 2021, Vol. 1796, No. 1, P. 12077.
- [25] A. P. Achilleos Et Al., "Scichallenge: A Social Media Aware Platform For Contest-Based Stem Education And Motivation Of Young Students," *Ieee Trans. Learn. Technol.*, Vol. 12, No. 1, Pp. 98–111, 2018, Doi: <https://doi.org/10.1109/Tlt.2018.2810879>.
- [26] S. Hamady, K. Mershad, And B. Jabakhanji, "Multi-Version Interactive Assessment Through The Integration Of Geogebra With Moodle," *Front. Educ.*, Vol. 9, P. 1466128, Sep. 2024, Doi: 10.3389/Feduc.2024.1466128.

-
- [27] A. M. B. Harsono, "Innovation In Steam Based Differentiation Learning Management," *J. Creat. Innov. Elem. Sch.*, vol. 1, no. 1.
- [28] H. Akram, A. H. Abdelrady, A. S. Al-Adwan, and M. Ramzan, "Teachers' perceptions of technology integration in teaching-learning practices: A systematic review," *Front. Psychol.*, vol. 13, p. 920317, 2022, doi: <https://doi.org/10.3389/fpsyg.2022.920317>.
- [29] Z. Marion, A. H. Abdullah, and S. N. S. A. Rahman, "The Effectiveness of the GeoGebra-Assisted Inquiry-Discovery Learning Strategy on Students' Mastery and Interest in Algebraic Expressions," *Int. J. Inf. Educ. Technol.*, vol. 13, no. 11, pp. 1681–1695, 2023, doi: 10.18178/ijiet.2023.13.11.1977.
- [30] S. A. Widodo, "Selection of Learning Media Mathematics for Junior School Students.," *Turkish Online J. Educ. Technol.*, vol. 17, no. 1, pp. 154–160, 2018.
- [31] A. Bhor and M. Varghese, "Steam-based teaching: Enhancing quality in education," *J. Educ.*, vol. 11, no. 2, pp. 323–331, 2024.