

INTEGRATING A STEAM-BASED MOOC AS A DIDACTIC AND PEDAGOGICAL SUPPLEMENT IN SCHOOL MATHEMATICS: A DESIGN-BASED RESEARCH STUDY

Sudirman Sudirman^{1*} , Bambang Avip Priatna Martadiputra² , Siti Faizah³ ,
Camilo Rodríguez-Nieto⁴ , Soeharto Soeharto^{5,6,7} , Zsolt Lavicza⁸ ,
Muhamad Galang Isnawan⁹ , Maximus Gorky Sembiring¹⁰ , Runisah Runisah¹¹ ,
Riska Juniar Suprihatin¹² 

¹Department of Mathematics Education, Universitas Terbuka (Indonesia)

²Universitas Pendidikan Indonesia (Indonesia)

³Universitas Negeri Malang (Indonesia)

⁴Universidad de la Costa (Colombia)

⁵Research Center for Education, National Research and Innovation Agency (BRIN), (Indonesia)

⁶Research Center of Educational Technologies, Azerbaijan State University of Economics, (Azerbaijan)

⁷Linz School of Education, Department of STEM Education, Johannes Kepler University, (Austria)

⁸Johannes Kepler University Linz (Austria)

⁹Universitas Nahdlatul Wathan Mataram (Indonesia)

¹⁰Universitas Terbuka (Indonesia)

¹¹Universitas Wiralodra (Indonesia)

¹²Universitas Negeri Jakarta (Indonesia)

*Corresponding author: sudirman.official@ecampus.ut.ac.id

bambangavip@upi.edu, faizah.siti.pasca@um.ac.id, crodrigu79@cuc.edu.co

soeharto@brin.go.id, zsolt.lavicza@jku.at, galangisna19@gmail.com, gorky@ecampus.ut.ac.id,

unisab@unwir.ac.id, riskajuniarsuprihatin@gmail.com

Received June 2025

Accepted January 2026

Abstract

Mathematics learning often presents challenges for students, particularly in understanding abstract concepts such as geometry, which has encouraged the development of various learning models and digital platforms. However, relatively few studies have examined technology-based learning supplements for school mathematics through a design-based research (DBR) approach. This study reports the design, development, and evaluation of a STEAM-based (Science, Technology, Engineering, Arts, and Mathematics) Massive Open Online Course (MOOC) intended to supplement didactic and pedagogical practices in junior high school mathematics. The study involved 31 junior high school mathematics teachers with more than ten years of teaching experience (14 females, 17 males) and 124 ninth-grade students (74 females, 50 males). Data were collected through interviews, classroom observations, platform practicality questionnaires, and geometry achievement tests, and were analysed using qualitative content analysis as well as descriptive and inferential statistics. The findings indicate that the developed STEAM-based MOOC demonstrates good levels of validity and practicality and is perceived as usable by both teachers and students. Quantitative results show substantial improvements in students' geometry understanding following the intervention. However, given the use of a single-group pre-post design

without a comparison group, these results should be interpreted as preliminary evidence rather than strong causal claims of effectiveness. Overall, the study highlights the potential of a STEAM-based MOOC, developed through an iterative DBR process, as a flexible and contextually relevant supplementary tool to support mathematics learning in schools, while also identifying areas for further refinement and future research.

Keywords – Design-based research, Didactic and pedagogical supplement, Geometry; MOOC, STEAM.

To cite this article:

Sudirman, S., Martadiputra, B.A.P., Faizah, S., Rodríguez-Nieto, C., Soeharto, S., Lavicza, Z., Isnawan, M.G., Sembiring, M.G., Runisah, R., & Suprihatin, R.J. (2026). Integrating a steam-based MOOC as a didactic and pedagogical supplement in school mathematics: A design-based research study. *Journal of Technology and Science Education*, 16(1), 125-146. <https://doi.org/10.3926/jotse.3633>

1. Introduction

The integration of technology in mathematics learning is now an increasingly urgent need in educational practices (Alabdulaziz, 2021; Barakabitze, William-Andey-Lazaro, Ainea, Mkwizu, Maziku, Matofali et al., 2019; Sudirman, Mellawaty, Yaniawati & Indrawan, 2020; Sudirman, Kusumah & Martadiputra, 2022; Yaniawati, Sudirman, Mellawaty, Indrawan & Mubarika, 2023). Technologies such as GeoGebra, Desmos, and AR/VR-based applications help teachers convey abstract mathematical concepts in a more visual, interactive, and easy-to-understand way (Cevikbas, Bulut & Kaiser, 2023; Chorney, 2022; Pahmi, Vrapı & Supriyadi, 2024; Sugiarni, Aulia, Suryadini, Bonyah & Olivero-Acuña, 2025; Wassie & Zergaw, 2019). In addition, MOOC learning platforms, Learning Management Systems (LMS), Google Classroom, Edmodo, and Canvas provide various features that support the creation of engaging, collaborative learning experiences, and enable structured and efficient evaluation of student achievement (Abidin & Saputro, 2020; Alabdulaziz, & Alhammadi, 2021; Fathema & Akanda, 2020; Ojeda-Castro, Murray-Finley & Sánchez-Villafañe, 2017; Taranto, Robutti & Arzarello, 2020; Taranto, Jablonski, Recio, Mercat, Cunha, Lázaro et al., 2021). However, the success of technology integration in learning depends not only on the availability of technology but also on the ability of teachers to apply it pedagogically (Prestridge & De-Aldama, 2016). Therefore, training and support for teachers are essential so that technology can be utilized optimally to improve the quality of learning.

Based on a preliminary investigation of mathematics curriculum documents and classroom observations in Indonesian public schools, two main interrelated problems were identified. First, the allocation of time for learning mathematics in the curriculum is considered inadequate to support students' understanding of complex and diverse material. This concern is echoed by Ramadhani and Haryani (2023), who found that low interest in mathematics correlates with poor problem-solving skills, suggesting that more time dedicated to engaging learning experiences could improve student outcomes. Second, teachers' learning management is often ineffective, either due to limitations in implementing innovative learning strategies or minimal use of relevant technology, which is consistent with the findings of Delima and Cahyawati (2021) and Bright, Welcome and Arthur (2024). Consequently, there is a need to develop a MOOC to support mathematics learning in the Indonesian context. This in effectiveness causes learning time to often be wasted on activities that do not support learning objectives, such as unstructured repetitive explanations or irrelevant activities. The combination of these two factors worsens students' ability to understand the material, especially mathematics.

Previous studies have attempted to address these problems by adopting various technology products such as e-learning (Anisa, Ginashantika, Sudirman & Olivero-Acuña, 2025; Mailizar, Almanthari, Maulina & Bruce, 2020; Mulqueeny, Kostyuk, Baker & Ocumpaugh, 2015). However, e-learning often faces

challenges, such as lack of direct interaction with students, lack of integration of learning with effective pedagogical approaches, and minimal support for the development of critical and collaborative thinking skills (Irfan, Kusumaningrum, Yulia & Widodo, 2020; Maatuk, Elberkawi, Aljawarneh, Rashaideh & Alharbi, 2022; Pani, Srimannarayana & Premarajan, 2015; Safira & Darmawan, 2025; Theelen & van-Breukelen, 2022). In addition, blended learning also faces obstacles in its implementation, such as difficulties in aligning online and face-to-face learning activities, lack of teacher readiness in designing and managing the combination of the two methods, and limited access to technology for some students (Ardiansyah, Fiyanti & Hamidah, 2021; Bayyat, Muaili & Aldabbas, 2021; Boelens, De-Wever & Voet, 2017; Rasheed, Kamsin & Abdullah, 2020; Umoh & Akpan, 2014). Consequently, there is a need to develop a MOOC to support mathematics learning in the Indonesian context.

In addition, based on literature reviews, researchers have used MOOCs in mathematics learning in schools to improve understanding of mathematical concepts (Contreras & Cacula, 2021), develop problem-solving skills (Li, Li, Zhu & Shadiev, 2023), and provide flexible access to learning materials for students. Researchers have also attempted to integrate the STEAM approach with online learning (Chen, Tang & Mou, 2019; Ekayana, Parwati, Agustini & Ratnaya, 2025), such as the study by Chang, Wang and Ku (2024), which examined the effects of STEAM-based online learning on students' understanding of artificial intelligence, creativity development, and creative thinking skills. Although previous studies have explored the integration of STEAM and online learning, the use of MOOCs integrated with STEAM as a complement to didactic and pedagogical practices in school mathematics —particularly in the Indonesian context, remains limited.

This gap indicates both a theoretical and practical opportunity to develop innovative approaches to school mathematics learning. Therefore, this study aims to analyse, design, develop, and evaluate a STEAM-based MOOC to complement didactic and pedagogical practices in school mathematics. Using a Design-Based Research (DBR) approach, the study focuses on integrating STEAM principles into the MOOC framework to support flexible and self-paced learning beyond traditional classroom settings. During the implementation phase, the STEAM-based MOOC serves as a supplementary tool to enhance the effectiveness of mathematics instruction by supporting both didactic strategies and pedagogical practices within the classroom environment.

2. Methods

2.1. Research Design

This study employed a DBR approach, as outlined by Bakker (2018). DBR was selected for its capacity to address complex educational challenges through iterative development and refinement. The rationale for adopting DBR includes: (1) its effectiveness in facilitating a deep understanding of mathematics learning issues, which is essential for developing targeted solution platforms; (2) its pragmatic orientation, ensuring that the solutions generated are responsive to the specific needs of both teachers and students; and (3) its integration of quantitative and qualitative research methods, which enhances the reliability and validity of the findings.

The DBR process in this study consisted of four interrelated stages that form a cyclical development framework:

1. **Practical Problems Analysis:** This initial stage aimed to identify key challenges in mathematics instruction, providing the foundation for formulating design principles to guide the development of a STEAM-based MOOC platform.
2. **Development of Solutions:** Based on the identified principles, the MOOC platform was designed through a series of focus group discussions (FGDs) and pilot trials involving both teachers and students. This iterative process culminated in the creation of the platform, accessible at <https://moocmath.id>.

3. Evaluation of Solutions in Practice: In this phase, the MOOC was implemented in real classroom settings to assess its effectiveness in enhancing mathematics learning. The evaluation focused on both pedagogical outcomes and user experiences.
4. Reflection on Design Principles: The final stage involved a comprehensive analysis of the platform's impact, focusing on how effectively it addressed the initial learning challenges. This reflective process provided insights into the strengths and limitations of the design, informing potential revisions and the development of generalizable design principles.

Together, these stages formed an iterative cycle of analysis, design, implementation, and reflection, enabling continuous validation and refinement to ensure that the STEAM-based MOOC was theoretically grounded and practically effective in supporting mathematics education. Each design-based research cycle contributed to the refinement of the MOOC and informed the formulation of design principles that guided subsequent stages of development. Accordingly, the primary focus of this study was not solely to measure learning gains, but to iteratively design, test, and refine a STEAM-based MOOC and to derive design principles to support its implementation in school mathematics.

In line with the principles of Design-Based Research, the construction and refinement of the research instruments and the STEAM-based MOOC were conducted through iterative validation phases integrated into the early design stages. During the initial design cycle, preliminary versions of the learning materials, platform features, practicality questionnaire, and learning test were reviewed through focus group discussions involving experienced mathematics teachers and educational technology experts. Feedback obtained at this stage was used to refine the structure, clarity, and alignment of the instruments with the intended STEAM learning objectives before field implementation. This formative validation process ensured that the instruments were not only technically appropriate but also pedagogically relevant, thereby strengthening the coherence between problem analysis, design decisions, and subsequent evaluation stages within the DBR framework.

2.2. Participants

This study involved three distinct groups of participants to ensure comprehensive data collection and analysis. The first group comprised 16 junior high school mathematics teachers (10 females and 6 males) aged between 25 and 45 years. These teachers participated in identifying and formulating key challenges related to mathematics instruction in schools. Their extensive classroom experience provided valuable insights into the contextual factors affecting mathematics teaching and learning.

The second group consisted of 15 junior high school mathematics teachers (4 females and 11 males), aged between 32 and 45 years, drawn from a diverse range of public and private schools across West Nusa Tenggara Province, Indonesia. All participants in both the first and second groups had more than 10 years of professional teaching experience in mathematics. The second group of teachers voluntarily participated in the practical evaluation of the STEAM-based MOOC developed in this study, providing critical feedback on its usability, relevance, and pedagogical effectiveness.

The third group comprised 124 ninth-grade students (74 females and 50 males), aged 15 to 16 years, from three public junior high schools located in remote areas of West Nusa Tenggara Province. These schools were selected due to their adequate internet connectivity, which was essential for the implementation of the MOOC. The selection of ninth-grade students was based on their demonstrated competence in operating computers and laptops, ensuring they could effectively engage with the MOOC platform. This diverse sample facilitated a robust analysis of the MOOC's impact on both teaching practices and student learning outcomes in mathematics.

2.3. Instrument and Data Collection

This study employed interviews, observations, platform practicality questionnaires, and achievement tests to collect data from teachers and students. The interviews aimed to explore the experiences of teachers

and students in mathematics learning, focusing on their interactions with the STEAM-based MOOC. Specifically, the interviews were conducted to gather feedback on the content, features, and usability of the platform, as well as to obtain insights for improving its design and ensuring its effective implementation in classroom settings. Observations were conducted to identify the instructional needs of both students and teachers, with an emphasis on analyzing how the STEAM-based MOOC could support more interactive, engaging, and effective teaching and learning practices.

The platform practicality questionnaire was designed to assess the usability of the developed STEAM-based MOOC, particularly the “Geometry in 3D” module. The instrument consisted of 10 items evaluated by teachers and students using a five-point Likert scale, complemented by an open-ended section to capture qualitative feedback. Practicality was examined across three dimensions: ease of use, efficiency, and attractiveness, which respectively reflect the platform’s user-friendliness, its effectiveness in supporting learning with minimal cognitive load, and the appeal of its design, content presentation, and interactivity. The questionnaire was developed based on relevant literature on educational technology usability and adapted to the context of mathematics learning. Content validity was established through expert judgment, yielding a moderate to good level of validity ($r = 0.52$), while internal consistency analysis indicated good reliability (Cronbach’s $\alpha = 0.81$), confirming that the instrument was appropriate for data collection.

An achievement test was administered to evaluate students’ understanding of the mathematical concepts presented in the STEAM-based MOOC and their ability to apply these concepts in problem-solving contexts. The test served to measure students’ mastery of key geometry concepts and to provide feedback for the iterative refinement of the MOOC, particularly in relation to content clarity, interactivity, and instructional organization. The geometry achievement test was developed based on the learning objectives and content covered in the MOOC and consisted of items assessing conceptual understanding. Content validity was established through expert judgment, yielding a good level of validity ($r = 0.62$), and the internal consistency analysis indicated good reliability (Cronbach’s $\alpha = 0.84$). The instrument was administered as both a pre-test and a post-test to examine changes in students’ understanding following the implementation of the STEAM-based MOOC.

To further clarify the construction of the achievement tests, the test items were developed based on the intended learning objectives of the “Geometry in 3D” module and aligned with the geometry topics addressed in the STEAM-based MOOC. The tests emphasized conceptual understanding and the application of geometric concepts in problem-solving contexts rather than procedural recall. Prior to implementation, the test blueprint and items were reviewed by mathematics education experts to examine content relevance, clarity, and alignment with the learning objectives. Feedback from this review was used to refine the wording and structure of the test items before their use in the pre-test and post-test stages.

| Instrument | Participants | Data Collected | Purpose of Data |
|-------------------------------------|-----------------------------------|--|---|
| Interviews | Mathematics teachers and students | Verbal responses and reflections | To explore experiences, perceptions, and challenges in using the STEAM-based MOOC |
| Classroom observations | Students and teachers | Field notes on learning activities | To identify instructional needs and examine the integration of MOOC with classroom learning |
| Platform practicality questionnaire | Teachers and students | Likert-scale responses and open-ended feedback | To assess usability, efficiency, and attractiveness of the MOOC |
| Achievement test (geometry) | Students | Pre-test and post-test scores | To measure students’ understanding of geometry concepts and learning gains |

Table 1. Summary of Instruments, Participants, and Data Sources

The development of the practicality questionnaire followed a structured process grounded in the literature on technology-enhanced learning and MOOC usability. Each statement was formulated to reflect the three assessed dimensions, ease of use, efficiency, and attractiveness, and their relevance to classroom implementation. Before administration, the questionnaire was reviewed by educational technology experts to ensure clarity, appropriateness of wording, and relevance to the context of secondary mathematics learning. Minor revisions were made based on expert feedback. In addition to Likert-scale responses, the inclusion of open-ended questions allowed participants to provide qualitative input that supported the interpretation of the quantitative practicality results. To provide a clearer overview of the research design, Table 1 summarizes the instruments used in the study, along with the participants and data sources.

2.4. Data Analysis

Data obtained from interviews and observations were analyzed using content analysis, which consisted of several stages: (a) data collection, (b) data familiarization, (c) open coding, (d) axial coding, (e) theme refinement, and (f) theme reporting. The overall content analysis process is illustrated in Figure 1.

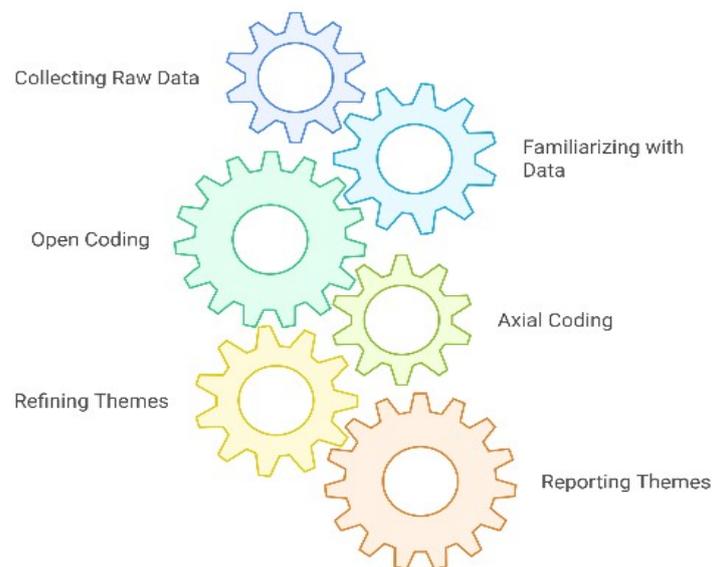


Figure 1. Content Analysis Process

Qualitative data were collected from interview responses, open-ended questionnaire answers, and classroom observations related to the use of the STEAM-based MOOC in mathematics learning. The analysis began with familiarization of the data to identify initial patterns. Open coding was then conducted to label meaningful units such as statements or actions, followed by axial coding to organize these codes into broader categories.

In the final stage, selective coding was applied to synthesize the categories into overarching themes. Initial codes such as multimedia support, project-based learning, and STEAM integration were grouped into categories including digital affordances of the MOOC, STEAM-oriented learning activities, and support for conceptual understanding. These categories were ultimately synthesized into two main themes: enhancement of conceptual understanding and transformation of didactical and pedagogical practices. The resulting themes were systematically reported and supported by representative participant quotations to ensure transparency and coherence in the qualitative analysis.

Quantitative data from the practicality questionnaire were analyzed using descriptive statistics by calculating the average final score for each of the ten statements, based on responses from both teachers

and students. The average scores were categorized using predefined assessment criteria derived from the mean and standard deviation, ranging from very impractical to very practical. In parallel, students' achievement test data were analyzed using a paired t-test to compare pre-test and post-test scores from the same sample. In addition to statistical significance testing, effect size was calculated using Cohen's d for paired samples to estimate the magnitude of students' learning gains following the implementation of the STEAM-based MOOC.

3. Results

In line with the design-based research approach, the results are organized to reflect the iterative phases of problem analysis, solution development, and evaluation. These phases illustrate how empirical findings from each stage informed the ongoing refinement of the STEAM-based MOOC and the emergence of design principles.

3.1. Practical Problem Analysis

The problem analysis was conducted through Focus Group Discussion (FGD) activities by conducting interviews with 16 mathematics teachers (five grade 7 teachers, seven grade 8 teachers, and four grade 9 teachers) representing 5 schools in Indonesia and conducted online. The interview in the first FGD activity lasted around 120 minutes and discussed issues related to (a) the problem of difficulties in teaching mathematics, (b) obstacles in managing mathematics learning in the classroom, (c) students' difficulties in following the learning process in the classroom, (d) teachers' obstacles in using technology in the classroom.

There are four important questions asked, namely: (a) what are the main difficulties you face when teaching mathematics concepts to students? (Q1) (b) What are the obstacles you often encounter in managing mathematics learning in the classroom, especially related to time, resources, or teaching methods? (Q2) (c) Based on your experience, what are the most common forms of difficulties experienced by students in understanding mathematics material during the learning process? (Q3) (d) What challenges do you experience in using technology to support mathematics learning in the classroom? (Q4).

Through interviews in the FGD, teacher representatives from each class provided input, as presented in Table 2.

| Classroom teacher | Question | Suggestion |
|-------------------|----------|---|
| Grade 7 Teacher | Q1 | Students have difficulty understanding abstract concepts such as sets. Differences in students' learning speeds. |
| | Q2 | Limited time to study the material. Lack of learning media. |
| | Q3 | Difficulty understanding fraction operations Lack of student practice at home. |
| | Q4 | Not all students hear instructions in class. Students no longer study at home. |
| Grade 8 Teacher | Q1 | Algebraic concepts are confusing to students because the symbols are difficult to understand. New material is difficult to understand due to a lack of understanding of previous material. |
| | Q2 | Textbooks are not interesting enough. Difficulty providing individual attention. |
| | Q3 | Confused about steps to solve algebra. Difficulty with story problems. |
| | Q4 | The Internet is often unstable. Teachers are not skilled enough in using applications. |

| Classroom teacher | Question | Suggestion |
|-------------------|----------|--|
| Grade 9 Teacher | Q1 | Geometry is difficult to understand, especially the Pythagorean theorem. Students find mathematics material complicated. |
| | Q2 | Too much material compared to time. Not all students have access to technology. |
| | Q3 | Difficulty understanding trigonometry because there are many formulas. Not able to relate mathematics to real life. |
| | Q4 | Applications are not in line with the curriculum. Students are not familiar with technology. |

Table 2. Summary of input from mathematics teachers

Table 2 summarizes feedback from grade 7, 8, and 9 mathematics teachers on challenges and solutions faced in classroom teaching. Grade 7 teachers highlighted difficulties in understanding abstract concepts such as sets and fractions, which were exacerbated by differences in students’ learning speeds and lack of practice at home. Grade 8 teachers noted difficulties in understanding algebra due to complex symbols and lack of prior understanding of the material, as well as issues of engagement with uninteresting textbooks and difficulties in providing individual attention. Grade 9 teachers expressed difficulties in understanding geometry and trigonometry, as well as limitations in relating mathematics to real life and inconsistencies in applications with the curriculum. In general, challenges that were frequently encountered in all classes were limited time, lack of appropriate learning media, unequal access to technology, and lack of technology skills among students and teachers.

Furthermore, comprehensive information obtained through interviews during the FGD activities was analysed using a content analysis approach. The results of the content analysis are presented in Figure 2.

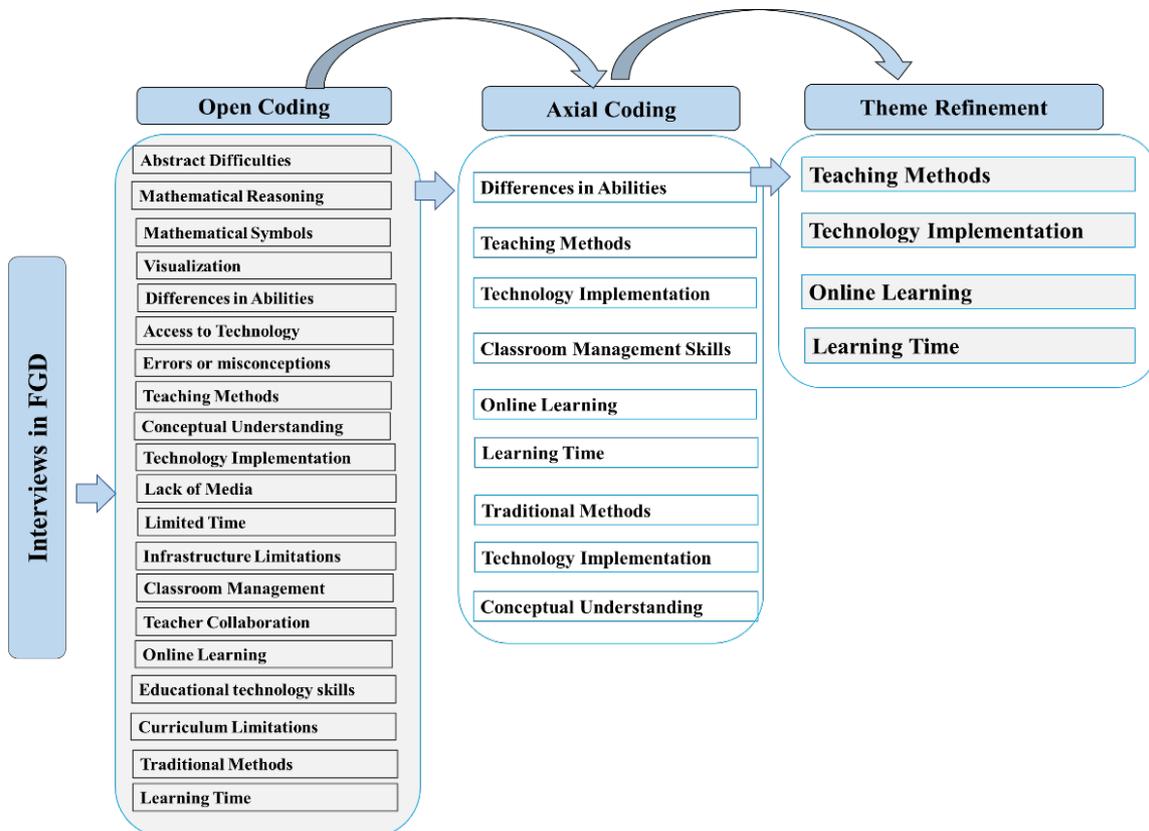


Figure 2. Results of content analysis from FGD Interviews

Based on the results of the content analysis, there are several practical problems that need attention, namely: first, the teaching methods applied by teachers have not been able to optimize learning in the classroom, which results in students having difficulty understanding the material optimally. Second, the application of technology in the classroom is less effective because it has not been utilized optimally to support an interactive and interesting learning process. Third, the time available for learning in the classroom is limited, so it is not enough to accommodate the diverse learning needs of students. Fourth, there is an urgent need for online learning that allows students to continue the learning process at home so that students can learn more flexibly and deeply without being bound by time constraints in the classroom.

3.2. Solution Development

In this study, solution development focuses on the design and development of mathematical pedagogical syntax in junior high schools that integrate STEAM-based MOOCs. There are six stages to teach mathematics, namely: (a) lesson planning, (b) introduction of material in class (offline), (c) exploration of material through MOOC (online), (d) collaboration in class (offline) for STEAM-based projects, (e) learning evaluation and feedback, and (f) reflection and skill development. This pedagogical syntax can be seen in Figure 3.

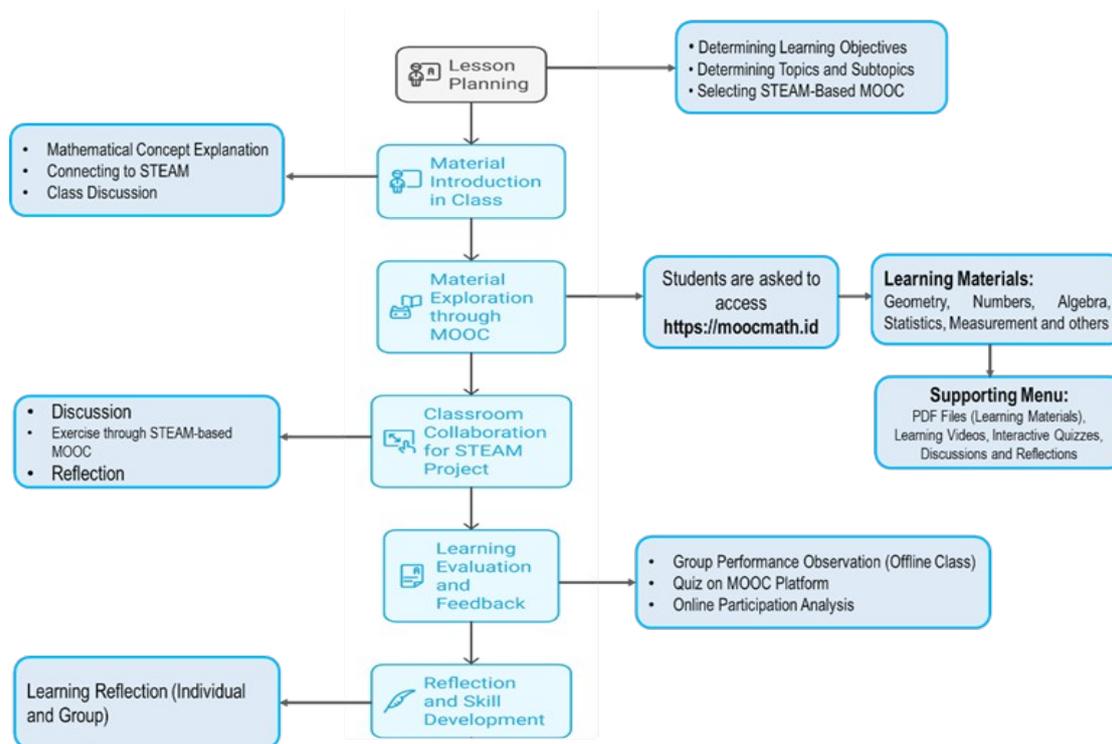


Figure 3. STEAM-Based MOOC pedagogical syntax

At the learning planning stage, researchers set learning objectives, and material topics, and select STEAM-based learning supplements through MOOC. Furthermore, at the material introduction stage, students are introduced to relevant mathematical concepts, connected to the STEAM approach, and involved in discussions to deepen understanding. In the supplement stage through MOOC, students can access the moocmath.id site which provides various mathematics materials, such as geometry, numbers, statistics, measurement, and algebra, complete with supporting menus such as downloads of teaching materials, learning videos, interactive quizzes, discussion rooms, and reflections. In the class collaboration stage for STEAM projects, students are involved in discussion activities, exercises through the MOOC platform, and reflections to develop further understanding. Evaluation and feedback are carried out through observations of group performances, quizzes on the MOOC platform as presented in Figure 4a

and 4b, and online student participation. In the final stage, reflections are carried out both individually and in groups to evaluate learning outcomes and improve student understanding.

The MOOC platform design (Figure 4) is designed to support learning by providing flexibility for students to choose materials that are relevant to offline classroom learning. For example, students can choose geometry topics according to their needs. After selecting the material, the platform automatically compiles the learning sequence that students must follow, providing clear guidance in the independent learning process.

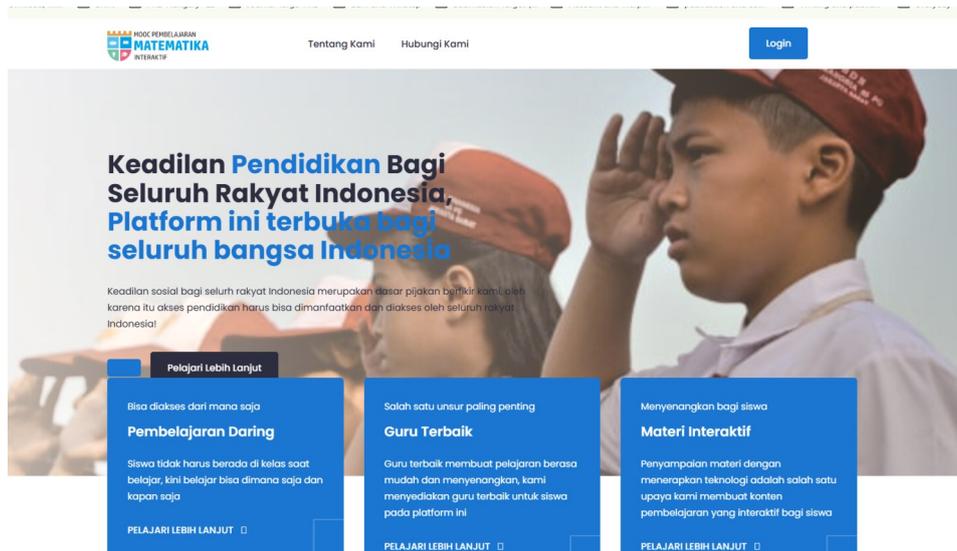


Figure 4a. MOOC Display login

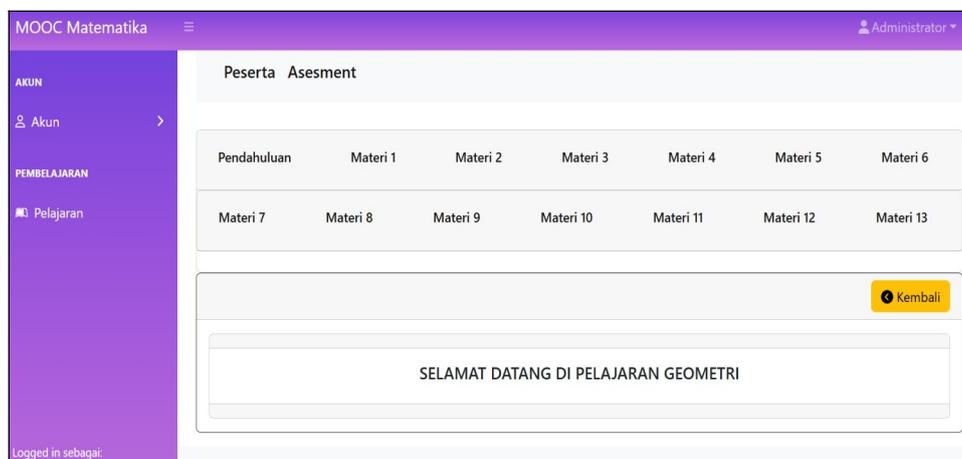


Figure 4b. MOOC Display Design

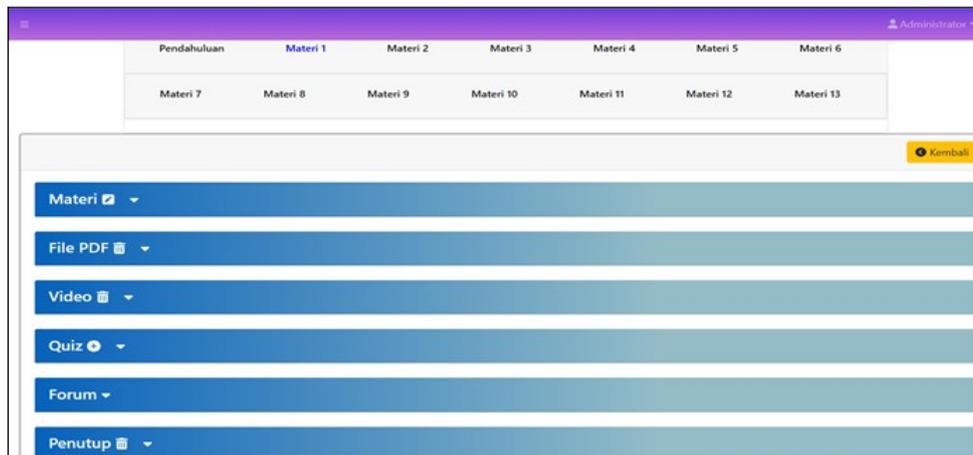


Figure 5. Menu in MOOC

When students open one of the materials, such as Material 1, the platform will display various learning support menus. The menu includes the main learning material, PDF files as additional references, learning videos to help visualize concepts, interactive quizzes to test understanding, discussion forums to discuss with friends or teachers, and a conclusion that summarizes the learning content (Figure 5). This design ensures that students get a structured, interactive, and collaborative learning experience. Furthermore, in the material and PDF menu, students can download teaching materials that are already integrated with STEAM. This can be seen in Figure 6.



Figure 6. Teaching Materials in MOOC

Drawing on the iterative cycles of the design-based research, in addition to outlining the pedagogical syntax and platform features, the development of the STEAM-based MOOC was guided by explicit design principles that distinguish it from a generic mathematics MOOC. Mathematics learning was intentionally embedded within STEAM contexts, where geometry concepts were connected to scientific phenomena, technological tools, and simple engineering-oriented activities to promote meaningful application. Digital technology was used not merely as a delivery medium, but as a cognitive tool to support visualization, interaction, and exploration, particularly for three-dimensional geometry concepts. In addition, the integration of online (MOOC) and offline (classroom) learning was designed to foster

collaboration and interdisciplinary thinking through STEAM-based projects, rather than isolated individual learning. The MOOC was positioned as a didactic and pedagogical supplement that emphasizes teacher mediation and classroom integration, making the design transferable to other school contexts seeking to implement STEAM-oriented mathematics learning. These design principles represent a synthesis derived across the iterative DBR cycles rather than a one-to-one mapping to individual cycles, capturing the cumulative refinements informed by analysis, implementation, and reflection stages.

3.3. Evaluation of Solutions In Practice

Three forms of solution evaluation were conducted in this study: (1) product validity evaluation, (2) practicality evaluation by teachers and students, and (3) evaluation of students' mathematical understanding after using the STEAM-based MOOC.

3.3.1. Evaluation of Product Validity by Experts

The STEAM-based MOOC product has been validated by three experts with a focus on ten main aspects, including learning design, clarity of objectives, accuracy, and relevance of materials, integration of STEAM components, student engagement, visual appearance, technology and interactivity, ease of navigation, accessibility, and learning evaluation. Mathematics learning experts assessed that the design had been designed according to STEAM principles and was able to encourage interactive student engagement. Mathematics material experts assessed that the content had high accuracy, relevance to the curriculum, and integration with other STEAM elements, although adjustments were needed to the level of difficulty of the questions. Learning technology experts assessed those technical aspects, such as interactivity and accessibility, supported the learning process optimally. This expert validation represents a continuation of the iterative validation process initiated during the early design stages, in which preliminary feedback from teachers and educational technology experts informed successive refinements of the instruments and platform prior to formal evaluation.

In addition, the validation results showed that this product was feasible to use with a high average score in all aspects. Some minor improvements, such as visual enhancements and the development of more varied evaluation tools, will be made before the field trial. This product is considered responsive, easy to use, and effective in supporting STEAM-based learning. The average value of each aspect can be seen in Table 3.

| No | Validated Aspects | Mean Score | | | |
|----|------------------------------------|------------|----------|----------|---------|
| | | Expert 1 | Expert 2 | Expert 3 | Average |
| 1 | Learning Design | 4.8 | 4.5 | 4.6 | 4.63 |
| 2 | Clarity of Objectives | 4.7 | 4.6 | 4.8 | 4.7 |
| 3 | Accuracy and Relevance of Material | 4.5 | 4.7 | 4.6 | 4.6 |
| 4 | Integration of STEAM Components | 4.6 | 4.6 | 4.7 | 4.63 |
| 5 | Student Engagement | 4.8 | 4.6 | 4.7 | 4.7 |
| 6 | Visual Display | 4.5 | 4.4 | 4.8 | 4.57 |

Table 3. STEAM-Based MOOC Validation Results

3.3.2. Evaluation of Practicality of STEAM-Based MOOC by Teachers

Based on the results of the practicality questionnaire analysis of the <https://moocmath.id> platform, an average practicality score of 4.13 was obtained, indicating that this platform is considered practical. This assessment is based on responses from 15 teachers to 10 statements related to the practicality of the platform. Most of the scores given by teachers ranged from 3 to 5, with a score of 4 being the most frequent value. Teachers with initials such as NH, MRM, and MA gave high scores, consistently at 4 and 5, indicating that they had a positive experience in using the platform. However, there were several low scores, such as 1 and 2, given by teachers IJH and M in certain aspects, indicating that there were elements in the platform that needed improvement.

In general, these results indicate that the STEAM-based MOOC platform has great potential to support mathematics learning, especially in terms of practicality. This platform is considered easy to access and use by the majority of teachers, but several teachers identified shortcomings that need attention. Adjustments to features or interfaces that are considered less practical can be a step to improve the overall practicality score. Thus, this platform can be more optimal in supporting mathematics teaching at various levels of education. The results can be shown in Table 4.

Furthermore, based on the content analysis of the interview data input from the 14 teachers, several pieces of information were obtained as in Figure 7.

Based on the research results, there are five main themes that teachers are concerned about revising in the platform being developed. The first theme is ease of access and identity, where teachers want more flexible access, especially in the login method. The use of NUPTK is considered difficult to remember, so teachers recommend using email as a login method. These results are in line with previous research which shows that ease of access and login flexibility are very important so that the platform can be used by various teachers with different ICT backgrounds.

| No | Teacher Initials | Average Score |
|----|------------------|---------------|
| 1 | NH | 4.5 |
| 2 | DAS | 4.0 |
| 3 | DF | 4.1 |
| 4 | S | 4.1 |
| 5 | DI | 4.3 |
| 6 | MRM | 4.5 |
| 7 | SH | 4.0 |
| 8 | IJH | 3.6 |
| 9 | ZS | 3.7 |
| 10 | MA | 4.8 |
| 11 | AJ | 4.3 |
| 12 | R | 4.0 |
| 13 | DF | 4.1 |
| 14 | M | 3.7 |

Table 4. Results of the STEAM-Based MOOC Practicality Test by Teachers

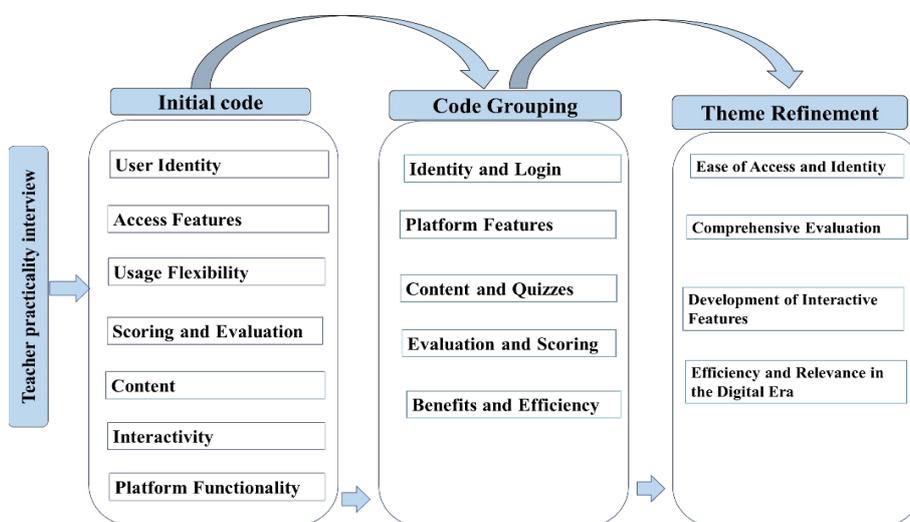


Figure 7. Content Analysis of Practicality of STEAM-Based MOOC by teachers

The second theme is the development of interactive features, which aims to strengthen collaboration between students, as well as between students and teachers. Better interactive features can facilitate more effective communication in learning, which has a positive impact on the quality of online learning. The third theme is material enrichment, where teachers expect systematic material with additional features such as equation formats to display mathematical symbols that support better mathematics learning.

The fourth theme is comprehensive evaluation, where teachers want a platform that can facilitate manual assessment for essay questions as well as various types of quizzes and evaluations that facilitate the use of various assessment techniques. The last theme is efficiency and relevance in the digital era, where teachers hope that this platform can help them improve the quality of mathematics learning and attract students' interest in learning. The results of this study support various previous theories and studies that emphasize the importance of these features in increasing the effectiveness and relevance of online learning platforms.

3.3.3. Evaluation of the Practicality of STEAM-Based MOOC by Students

Based on the results of limited trials with students, information was obtained that the <https://moocmath.id/> platform is classified as practical with an average value of 3.65. In other words, students consider that the platform has met the aspects of efficiency, ease, and attractiveness. The results of the limited trial can be seen in Table 5.

| No | Student Initials | Average |
|----|------------------|---------|
| 1 | KM | 3.9 |
| 2 | MHT | 4.4 |
| 3 | MAH | 4 |
| 4 | HGG | 3.9 |
| 5 | RF | 3.6 |
| 6 | NRA | 3.1 |
| 7 | EW | 4 |
| 8 | ZDS | 3.5 |
| 9 | SH | 4 |
| 10 | LR | 3.4 |

Table 5. Results of Practicality Test by Students

Based on the results of limited trials on students, the <https://moocmath.id/> platform showed a fairly high level of practicality with an average score of 3.65. This shows that students consider the platform to be efficient, easy to access, and interesting. Based on data obtained from 10 students who took part in the trial, the average score for each student varied between 3.1 and 4.4, with the overall average showing that this platform has met important aspects in efficient and effective online learning. In the initial step of thematic analysis, the researcher read the data transcript several times to make it easier to determine the initial code. The student input transcript can be seen in Figure 8.

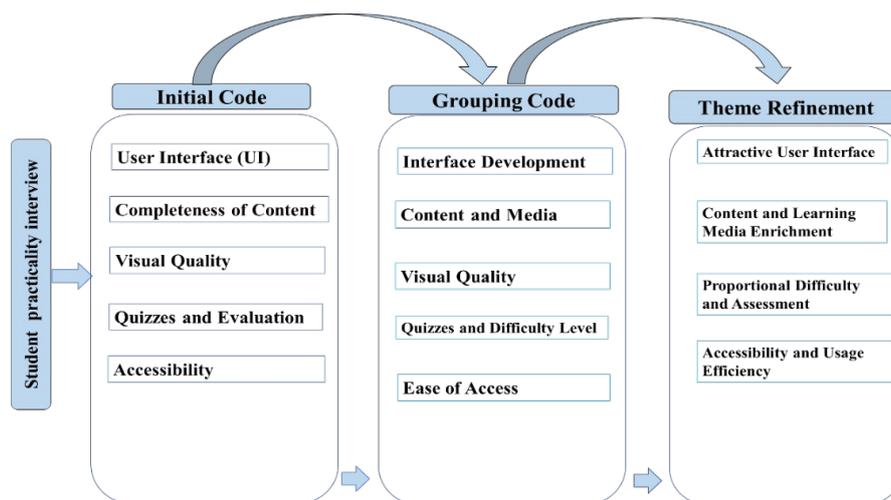


Figure 8. Content Analysis of Students' Practicality Test

The first theme that student's input was the appearance of the interface or background of the platform. Students expect the platform to have an attractive appearance, including colors and the use of day or night mode. The use of day and night mode makes users more comfortable when using the platform. In addition, students also expect the addition of animations to attract students' interest in using the platform.

3.3.4. Evaluation Based on Understanding Test on Geometry Material

After students implemented STEAM-based MOOC learning, at the end of the meeting the teacher gave a post-test of geometry understanding, which aimed to evaluate the effectiveness of STEAM-based MOOC learning. The results of the descriptive statistical analysis can be seen in Table 6.

| | Pre-test (N=124) | Post-test (N = 124) |
|-------------------------|------------------|---------------------|
| Average (M) | 32.46 | 72.56 |
| Standard deviation (SD) | 10.26 | 8.39 |

Table 6. Results of Descriptive Statistical Analysis

Based on the results of the pre-test and post-test conducted on 124 students, there was a significant increase after the STEAM-based MOOC learning intervention. The average student score in the pre-test was 32.46, with a standard deviation of 10.26, indicating that students' test results initially varied quite significantly. After learning, the average score increased to 72.56, while the standard deviation decreased to 8.39, indicating that although there was a significant increase in the average, the variation in scores between students tended to be more uniform. The results indicate a substantial increase in students' post-test scores compared to the pre-test, accompanied by a reduction in score variability. This suggests that students' performance became more consistent following the implementation of the STEAM-based MOOC.

To test the normality of the data, the Kolmogorov-Smirnov test was conducted. At $\alpha = 0.05$, statistical tests on the pre-test scores ($q = 0.290$) and post-test ($q = 0.200$) showed that the data were normally distributed. After achieving normality, a paired sample t-test was conducted on the scores obtained from the pre-test and post-test results. At $\alpha = 0.05$ and $q = 0.000$, it was concluded that there was a significant difference in the results of the students' understanding test, especially in geometry material. To further complement the pre–post comparison, the magnitude of the observed improvement was examined using effect size analysis. The calculated effect size (Cohen's $d = 4.28$) indicated an extremely large effect, suggesting that the increase in students' geometry understanding after using the STEAM-based MOOC was not only statistically significant but also educationally meaningful. This result provides stronger quantitative evidence to support the test findings and complements the qualitative results related to student engagement and learning experiences.

3.4. Reflection

3.4.1. Reflection on Product Validity Evaluation

The process of evaluating the validity of the STEAM-based MOOC product showed very positive results, reflecting that the design and content presented were by the expected standards. The assessment received illustrates that this product can present an interesting and effective learning experience, which integrates STEAM principles well. Although the overall validity score is very adequate, there are still some areas that can be improved, such as improving the visual appearance and developing more varied evaluations. This reflection emphasizes the importance of conducting a comprehensive evaluation to ensure that the product developed not only meets academic standards but can also provide a richer and deeper learning experience for its users.

3.4.2. Reflection on Practicality Evaluation by Teachers

The evaluation of the practicality of the product by teachers provides an overview that this platform is generally easy to use and supports the smooth running of the teaching process. Most teachers appreciate the simplicity of access and use of this platform, which allows them to focus on managing learning more efficiently. However, some aspects, such as ease of login and a more user-friendly interface, still need more attention. This reflection shows that although practicality is one of the main strengths, teacher feedback indicates the need for adjustments to make the platform more accessible and more appropriate to teaching needs in the field.

3.4.3. Reflection on Student Practicality Evaluation

From the students' perspective, the STEAM-based MOOC platform was also considered easy to use and presented a fun learning experience. However, some students emphasized that improvements in the interface and the addition of animation features could further increase their engagement. By paying attention to the visual aspects and user experience, the platform has the potential to attract more students' interest and encourage active participation in learning. This reflection shows that it is important to adapt the platform based on student feedback to create a more fun and effective learning experience, and to ensure that the platform remains attractive to various types of learners.

3.4.4. Reflection on Student Mathematical Understanding Test Evaluation

The evaluation of students' mathematical understanding after learning using the STEAM-based MOOC showed encouraging results, with a significant increase in their understanding of geometry concepts. Better test results and a reduction in standard deviations indicate that MOOC-based learning can help to equalize learning outcomes among students. This reflection underlines the importance of using appropriate evaluations to measure learning effectiveness, which not only includes individual improvement but also shows uniformity in student understanding. The decrease in score variation indicates that the material taught through MOOCs has succeeded in touching various learning styles and can reduce the gap in understanding that often occurs in the classroom.

4. Discussion

The use of STEAM-based MOOC as a didactic and pedagogical supplement to mathematics in schools has great potential to improve the quality of student learning. This is because STEAM-based MOOC is systematically designed to integrate the stages of the STEAM approach. The teaching materials available in MOOC follow the stages of STEAM learning. In addition, the material in MOOC is presented in interactive formats such as videos, simulations, and quizzes, which make the learning process more interesting and encourage active student involvement. With flexible access, students can also learn anytime and anywhere according to their needs, both in and outside the classroom.

An important contextual contribution of this study lies in its implementation in schools with limited internet connectivity. The STEAM-based MOOC was designed as a supplementary learning tool that can be flexibly

integrated with offline classroom activities, making it suitable for remote or resource-constrained school contexts. This highlights the relevance of the proposed design beyond well-resourced urban settings.

The findings of this study are consistent with previous research (Aina & Ogegbo, 2021; Faridi & Shaheen, 2024; Jona & Naidu, 2014), which suggests that MOOCs can improve learning quality, increase student engagement, and facilitate personalized learning. This is because students can learn at their own pace and access additional materials to strengthen mathematical understanding (Gonda, Ďuriš, Pavlovičová & Tírpáková, 2020). The use of MOOCs also allows teachers to provide differentiated learning, according to students' ability levels and interests (Bustamante-León, Herrera, Domínguez-Granda, Schellens, Goethals, Alejandro et al., 2022).

The results of this study are also in line with the theory that online learning platforms should be an alternative to help students carry out learning or help teachers improve the quality of mathematics learning in schools (Fernández-César, Prada-Núñez & Pinto, 2024; Othman, Jaini, Ismail, Zainoddin, Radzi & Sundram, 2023). The results of this study are also in line with several previous studies (Makruf, Rifa'i & Triana, 2022) which revealed that online learning platforms tend to have a positive impact on mathematics learning. Moreover, when the platform integrates STEM (Ibrahim, Herwin, Retnawati, Firdaus, Umar & Mufidah, 2024; Sevimli & Ünal, 2022).

The quantitative results revealed a statistically significant improvement in students' geometry understanding, accompanied by a very large effect size. However, although the magnitude of learning gains is substantial, the results should be interpreted with caution due to the use of a single-group pre-post design without a comparison group. Therefore, the findings provide preliminary evidence suggesting that the use of a STEAM-based MOOC is associated with improvements in students' mathematical understanding, particularly in geometry. Future studies employing comparison groups are needed to establish stronger causal evidence regarding the effectiveness of the STEAM-based MOOC.

It is important to note that both MOOCs and STEAM approaches in mathematics education have been widely explored in previous studies. Therefore, the contribution of this study does not lie in introducing MOOCs or STEAM as entirely new concepts. Rather, the contribution of this work resides in the design and implementation of a STEAM-based MOOC as a didactic and pedagogical supplement within formal classroom instruction, developed through a design-based research approach. By articulating explicit design principles and demonstrating how online and offline learning are integrated in an authentic school context, this study provides insights that can inform similar implementations in other educational settings. Viewed through a design-based research lens, these findings illustrate not only learning outcomes, but also the iterative refinement of the MOOC design and the emergence of design principles that can inform similar implementations in school mathematics contexts.

In addition, the material on the platform can be divided into several sub-chapters and contains an equation format. The equation format is a format that can be used to enter several symbols or formulas in mathematics. This format is usually a standard format in mathematics learning platforms. The results of this study are then in line with several previous studies by Daniel and Bird (2019) which revealed that learning platforms should contain systematic materials and supporting features that are by the characteristics of the subject, such as equations and PowerPoint. In addition, the evaluation stages in MOOCs help students to work on mathematical exercises anytime and anywhere. The exercises presented in the form of quizzes make it easier for teachers when they want to use various assessment techniques. This is intended because each assessment has its own goals or characteristics (Mahlambi, 2021; Muchlis, Ibnu, Subandi & Marfuah, 2020; Sudirman, García-García, Rodríguez-Nieto & Son, 2024; Yang & Xin, 2022), depending on the teacher's needs. The results of this study are also in line with several previous studies by Al-Maqbali and Al-Shamsi (2023) which revealed that online learning platforms should contain evaluation features to make it easier for teachers to find out students' achievements or developments. These findings suggest that the use of a STEAM-based MOOC is associated with substantial improvements in students' mathematical understanding, particularly in geometry.

5. Conclusion

The results of this study provide preliminary evidence that the use of a STEAM-based MOOC as a didactic and pedagogical supplement to mathematics learning is associated with improvements in students' mathematical understanding and demonstrates potential as a valid and practical learning tool. In terms of validity, the design and content of the MOOC meet expected standards and demonstrate appropriate integration of STEAM principles, although improvements in visual appearance and evaluation variations should be considered to further enhance product quality. From a practicality perspective, the platform is perceived as easy to use by both teachers and students and supports a smooth learning process, while feedback indicates the need for improvements in interface design, ease of login, and the inclusion of more interactive features to optimize user experience. In addition, the evaluation of students' mathematical understanding indicates an increase in conceptual understanding and more consistent learning outcomes across different learning styles, within the limitations of the study design. Overall, based on reflection across all evaluation aspects, the developed platform shows potential to support more inclusive and engaging mathematics learning experiences and represents a promising approach to technology-enhanced learning in school mathematics.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received financial support from Universitas Terbuka through the Research Grant Scheme 2025 for the research, authorship, and/or publication of this article.

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Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2026 (www.jotse.org)



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