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DEVELOPMENT OF STEAM-BASED LEARNING MEDIA THROUGH LESSON STUDY FOR ELEMENTARY SCHOOL TEACHERS

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Abstract
This study aims to develop STEAM (Science, Technology, Engineering, Arts, and Mathematics)-based learning media with a lesson study approach to improve the quality of learning in Elementary Schools in Cisolok District. The method used in this study is development (Research and Development/R&D) with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. In the analysis stage, student needs and STEAM challenges are identified through initial observations and interviews. The media design is prepared based on the results of the analysis, and developed through a prototype that is tested in class. Implementation is carried out in Elementary Schools in Cisolok District, with data collection through observation, questionnaires, and interviews to measure student and teacher responses to the media developed. The collected data are analyzed quantitatively and qualitatively, using descriptive statistics for questionnaires, and qualitative analysis of interviews to understand teacher experiences and challenges in lesson study. Statistical tests are conducted to evaluate changes in student engagement and improvements in teacher competence. The results of the study indicate that the developed STEAM-based learning media can increase student engagement in the learning process. In addition, teacher collaboration in lesson study has proven effective in improving teacher professional competence, especially in designing and implementing innovative learning media. This study contributes to the development of learning media that are more relevant to students' needs and provides solutions to challenges in STEAM-based learning in elementary schools.
Keywords: *STEAM; instructional media; lesson study; elementary school*

Abstrak
Penelitian ini bertujuan untuk mengembangkan media pembelajaran berbasis STEAM (Science, Technology, Engineering, Arts, and Mathematics) menggunakan pendekatan lesson study guna meningkatkan kualitas pembelajaran di sekolah dasar di Kecamatan Cisolok. Metode yang digunakan penelitian ini pengembangan (Research and Development/R&D) dengan model ADDIE (Analysis, Design, Development, Implementation, and Evaluation). Tahap analisis, kebutuhan siswa dan tantangan STEAM diidentifikasi melalui observasi awal dan wawancara. Desain media disusun berdasarkan hasil analisis, dan dikembangkan melalui prototipe yang diuji di kelas. Implementasi dilakukan di sekolah dasar di Kecamatan Cisolok, dengan data dikumpulkan melalui observasi, angket, dan wawancara untuk mengukur respons siswa dan guru terhadap media yang dikembangkan. Data yang dikumpulkan dianalisis secara kuantitatif dan kualitatif, dengan menggunakan statistik deskriptif untuk angket, serta analisis kualitatif terhadap wawancara untuk memahami pengalaman dan tantangan guru dalam lesson study. Uji statistik dilakukan untuk mengevaluasi perubahan keterlibatan siswa dan peningkatan kompetensi guru. Hasil penelitian menunjukkan bahwa media pembelajaran berbasis STEAM yang dikembangkan dapat meningkatkan keterlibatan siswa dalam proses pembelajaran. Selain itu, kolaborasi guru dalam lesson study terbukti efektif dalam meningkatkan kompetensi profesional guru, terutama dalam merancang dan mengimplementasikan media pembelajaran yang inovatif. Penelitian ini berkontribusi pada pengembangan media pembelajaran yang lebih relevan dengan kebutuhan siswa serta memberikan solusi terhadap tantangan dalam pembelajaran berbasis STEAM di sekolah dasar.
Kata Kunci: STEAM; media pembelajaran; lesson study; sekolah dasar

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Introduction

The use of learning media at the elementary level is very important to strengthen students' understanding of basic concepts and create a more interesting and interactive learning experience for them. At elementary school age, children find it easier to understand material when presented visually and practically than just text-based, because learning media can involve more senses in the process of receiving information (Sudirman et al., 2024 & Wahyuningtyas & Sulasmono, 2023). Without adequate media, students often find it difficult to understand the material in depth and tend to be less enthusiastic in following lessons (Mutiara Putri et al., 2020; Putri & Nurafni, 2021; Winda & Dafit, 2021). The use of this media has even become an important need to increase the effectiveness of learning in the classroom (Mahnun, 2012; Gawise et al., 2022; Lestari et al., 2018). However, in reality, many elementary school teachers still face obstacles in developing and providing relevant and innovative learning media. This is often influenced by a lack of skills in designing appropriate media and limited ideas, tools, and materials needed (Mutiara Putri, 2017).). In addition, many teachers in Indonesia experience limited supporting facilities and infrastructure in schools, which contributes to their difficulties in creating effective learning media (Nissa, Siti Faizatun dan Renoningtyas, 2021). These obstacles show how urgent the need for more adequate training and support for teachers is in developing learning media that are appropriate to the needs of students in elementary schools.

Today, technology is created and developed to facilitate human life, including in the field of education. However, learning media can also be created from materials available in the surrounding environment, including natural or recycled materials (Sulistyorini & Listiadi, 2022; Harsiwi & Arini, 2020; Hanannika & Sukartono, 2022; Faqih, 2021). The more sensory organs used to receive and process information, the greater the likelihood that the information will be understood and retained in memory. With the presence of educational media, students are expected to easily and effectively receive and absorb messages presented through their senses (Rejeki et al., 2020).

In line with the need for effective educational media, the STEAM approach has emerged as an innovative solution that not only utilizes available materials but also integrates various disciplines to foster students' creativity and problem-solving skills. STEAM is a learning paradigm originating from the United States. In South Korea, STEAM education has been emphasized since 2011 to encourage creativity and national competitiveness (Kim & Bolger, 2017& Kang, 2019). STEAM stands for science, technology, engineering, arts, and mathematics, where teachers act as facilitators and students are the central focus of the learning process, whether inside or outside the classroom (idam ragil wa, 2020; Hasanah, 2022; Quigley et al., 2020; Chung et al., 2022). STEAM supports and demonstrates critical thinking and creative problem-solving skills as essential tools for the future (Quigley, Shekell, et al., 2020 & Sudirman et al., 2024). Recent studies have shown promising results in STEAM learning, where products developed through STEAM learning often utilize natural or even recycled materials By integrating various fields of knowledge into learning, this approach can also train students in problem-solving skills necessary to contribute more effectively to sustainable development in the present and future(Mutiara Putri, 2022).

However, despite its proven effectiveness in many developed countries, the implementation of STEAM at the elementary school level in Indonesia is still relatively new

and uneven. Many teachers face challenges in developing and implementing STEAM-based educational media that is suitable for elementary school learning contexts. Limited knowledge about integrative methods and lack of facility support make it difficult for teachers to integrate the disciplines of science, technology, engineering, arts, and mathematics into a single, effective educational medium. Therefore, innovation in the development of educational media that supports the implementation of STEAM is greatly needed.

To overcome the challenges in implementing STEAM, a strategy is needed that not only focuses on learning media but also empowers teachers in developing and implementing it. Lesson Study emerges as a potential solution that allows teachers to collaborate, exchange ideas, and improve skills in integrating STEAM aspects into learning. This approach supports improving teacher competency, especially in designing and using innovative educational media. Lesson Study is a collaborative process where a group of teachers work together to plan, execute, and evaluate lessons aimed at improving classroom teaching practices. Through Lesson Study, teachers can share ideas, reflect on teaching practices, and continuously improve teaching strategies. The use of Lesson Study in developing STEAM-based educational media will provide teachers with the opportunity to learn and innovate together, resulting in more effective educational media that meets the needs of elementary school students (Dewi et al., 2021; Purwulan, 2023; Yulianto & Firman, 2021).

Lesson Study consists of three stages known as Plan-Do-See. The entire process involves lesson planning, implementation, and observation and reflection. In the context of STEAM-based learning, Lesson Study provides an opportunity for teachers to test, evaluate, and refine the media developed through a continuous collaborative cycle. Although many studies have addressed learning issues that can be addressed by teachers through Lesson Study, there are still few studies focusing on the development of STEAM-based educational media through this approach. Therefore, this study aims to fill that gap by developing STEAM-based educational media that can help teachers improve their competency in designing innovative media, while also strengthening learning at the elementary level.

The objective of this research is to develop STEAM-based educational media through the Lesson Study approach and analyze how teacher collaboration can enhance their ability to address the challenges of STEAM teaching. Additionally, this research will explore the impact of Lesson Study in improving the effectiveness of the developed educational media, particularly in the context of primary education. The results of this study are expected to be a relevant practice model not only for teachers in Cisolok District, but also for teachers in other areas who face similar obstacles, as well as contribute to the professional development of teachers in implementing STEAM-based learning.

Research Methods

The research design utilized is an Educational Research and Development (R&D) model, with stages tailored to the ADDIE framework (Analysis, Design, Development, Implementation, and Evaluation).

Analysis: In this initial stage, the researcher identified problems faced by elementary schools in Cisolok Subdistrict through surveys distributed to teachers, classroom observations, and a literature review to understand the needs for STEAM-based learning. The analysis provided insights into which topics should be emphasized in the development of educational media and how lesson study could support this development.

Design: Following the analysis, the next step was to design educational media aligned with STEAM principles. This phase involved developing the technical specifications, creating

interactive learning methods, and integrating the various disciplines within STEAM. Simultaneously, this stage was integrated with the planning phase of the lesson study, where elementary school teachers in Cisolok Subdistrict collaborated to plan the use of STEAM-based educational media. They discussed how the media could be used to teach specific topics, how STEAM integration would be carried out, and how student responses could be measured. The lesson study approach was used to collaboratively design the learning scenarios with the teachers.

Table 1. Agenda of Lesson Study Activities for Elementary School Teachers in Cisolok Subdistrict

Day, Date	Agenda
Friday, August 2, 2024	Seminar on the development of STEAM-based educational media
Saturday, August 3, 2024	Continuation of the seminar on the development of STEAM-based educational media
Friday, August 9, 2024	Workshop on creating STEAM teaching modules/lesson plans
Saturday, August 10, 2024	Discussion and continuation of the workshop on creating STEAM teaching modules/lesson plans
Thursday, August 15, 2024	Workshop on developing STEAM media
Friday, August 16, 2024	Discussion and continuation of the workshop on developing STEAM media
Friday, August 23, 2024	Implementation of STEAM learning tools in lower grade classes
Saturday, August 24, 2024	Reflection on the implementation of STEAM learning tools in lower grade classes
Friday, August 30, 2024	Implementation of STEAM learning tools in upper grade classes
Saturday, August 31, 2024	Reflection on the implementation of STEAM learning tools in upper grade classes followed by the closing ceremony of the STEAM program and social gathering

Development: Based on the design, the educational media is developed, which can include instructional aids, applications, modules, or other interactive forms of media that support STEAM learning. The developed media is then internally tested and validated by experts, such as STEAM education specialists or educational technology experts.

Implementation: After the media is developed, a limited-scale trial is conducted in several elementary schools in the Cisolok Subdistrict. This trial is carried out within the framework of lesson study, where teachers collaborate to plan, implement, and evaluate the use of the media in real classroom settings. The development and implementation phases are integrated into the "Do" stage of the lesson study cycle, where, following the planning stage, the educational media is tested in classrooms. The involved teachers implement the developed media by engaging students in STEAM activities, and peer teachers observe student activities to assess the effectiveness of the media in enhancing students' skills and understanding.

Evaluation: Evaluation is carried out at every stage of the development process. Using questionnaires, interviews, and observations, teachers and students provide feedback on the educational media used. This feedback is then utilized to refine the media before it is

disseminated more broadly. Similarly, the evaluation phase is integrated into the "See" stage of the lesson study, where teachers collectively reflect on the teaching process using the developed media. The results of this reflection serve as a basis for further improvement of the educational media and its implementation strategies.

Data processing was conducted using a mixed-method approach, where qualitative data served as the primary data source and quantitative data acted as preliminary or supplementary information. Qualitative data were obtained through interviews with teachers, observational notes during lesson study activities, and teachers' reflections on the teaching process. This provided a deep understanding of the challenges and opportunities in implementing STEAM-based educational media. Surveys were conducted prior to the use of STEAM-based educational media to assess teachers' needs and their initial knowledge of STEAM and lesson study activities. This quantitative data can be analyzed using statistical tests to determine whether there is a significant difference in student learning outcomes before and after the implementation of the media.

The research subjects included elementary school teachers from Cisolok Subdistrict who participated in the lesson study activities. These teachers were from one cluster, namely the Ganesa cluster, which consists of seven elementary schools with a total of 30 teachers, as well as students from the classes where the STEAM-based educational media was tested. The sample was selected purposively, focusing on teachers who were actively involved in the lesson study and students from various elementary schools that were willing to participate in the media trial.

Data Collection Instruments, base on questionnaires**:** Distributed to teachers to gather initial information regarding their needs and knowledge about STEAM and lesson study activities. Observation, used to observe how teachers and students interact with the educational media during the lesson study. Observations were conducted during the implementation of the media in the classroom. Interviews, conducted with teachers to gain deeper insights into their experiences using STEAM-based media and their reflections on the lesson study activities. Interviews were also held with students to collect data on their perceptions of the developed media, as well as to assess their levels of anxiety and the skills they acquired.

Result and Discussion

This research began with gathering information on the needs of elementary school teachers through a questionnaire. The questionnaire included questions about teaching experiences, curriculum and teaching material needs, the use of technology in education, professional development and training needs, and challenges in teaching. Based on the results from the questionnaire distributed to 30 elementary school teachers, 13% had teaching experience of 4-6 years, while the remaining 87% had been teaching for more than 6 years.

The results of the questionnaire illustrated various challenges and needs faced by teachers in teaching. According to the teachers, the readiness of students to receive teaching materials varied considerably. Teachers assessed that only 42% of their students were very ready to receive the material, while the majority, 58%, appeared only moderately ready. This indicates a need for more intensive efforts to build student readiness for learning. This may also be due to a lack of motivation or inadequate foundational skills, requiring teachers to be more creative in designing teaching strategies that can enhance student engagement and readiness, because teachers have an important role in preparing students who are ready to face the future.(Abidah et al., 2022 & Putu et al., 2021)

Furthermore, regarding the alignment of teaching materials with the curriculum, 33% of teachers stated that the available teaching materials were aligned with the applicable

curriculum. However, the majority, namely 67%, considered that the teaching materials were only quite appropriate. This shows a gap between teaching materials and the actual needs of students in the field. Many teachers feel the need to complete or modify existing teaching materials. As many as 67% of teachers often adjust teaching materials, while 33% of teachers only occasionally make modifications. This is in accordance with the opinion (Sari & Makaria, 2022) that if teachers are not ready or unable to modify teaching materials, students can experience a decrease in interest in learning or even lose motivation to improve their academic achievement. However, this condition shows that teachers have a high initiative to adapt teaching materials, but also shows the need for a more flexible and responsive curriculum development process that takes into account student needs.

The main challenges faced by teachers in developing lesson plans also varied. A total of 12% of teachers mentioned the lack of resources or teaching materials as a constraint, 26% felt limited by the available time, and 62% considered that aligning the materials with student needs was the biggest challenge. This shows that teachers understand the importance of designing lesson plans that are relevant to students' conditions, but they still face difficulties in implementation. Resource and time constraints are also significant challenges, indicating that additional support, both in terms of materials and time, is needed by teachers to design effective and comprehensive lessons. Limitations have indeed become problems that are a challenge in improving the quality of educational institutions (Rahman & Akbar, 2021).

Regarding the use of technology as a teaching medium, respondents showed varying frequencies. A total of 9% of teachers reported rarely using technology, while 19% used technology daily. About 31% used technology several times a month, and 41% used it several times a week. However, 3% of teachers felt less skilled in using technology for teaching, while 69% felt sufficiently skilled, and 28% considered themselves highly skilled. Interestingly, all the respondents, or 100%, felt that they still needed further training on the use of technology in education. The fact that all teachers expressed a need for further training in technology use indicates that technological skill development requires more attention. This aligns with the professional training needs identified by teachers, where project-based learning and the use of educational technology were the main priorities. Even experienced teachers felt the need to continuously update their skills through training, with 58% participating in training every semester (Susilo & Sarkowi, 2018 & Eliza et al., 2022)

Additionally, teachers expressed their need for training and professional development in several key topics. Effective education requires the development of teachers' professional competencies as the main foundation. These professional competencies are very important, especially today, because teachers are not only required to teach, but also to carry out their role as competent and highly dedicated educators. Teachers' ability to understand the material, master relevant teaching methods, and adapt to dynamic educational developments are crucial factors in creating a productive learning environment and supporting student growth as a whole. Without adequate competencies, teachers will find it difficult to provide effective and meaningful learning for students (Solikhulhadi, 2021). The topics considered necessary for development included the use of educational technology (9%), assessment and evaluation of learning (13%), classroom management (14%), lesson plan development (16%), differentiated instruction (17%), and project-based learning as the top priority, with 31% of teachers expressing interest. Although teachers frequently participated in educational workshops or training sessions, their participation frequency varied. About 58% of teachers attended training every semester, 21% rarely participated, 12% attended monthly, and 9% participated annually.

Teachers also identified the main challenges in teaching. A total of 9% of teachers perceived a lack of parental involvement, 18% mentioned the lack of resources or teaching materials, 23% considered time constraints a challenge, and half of the respondents (50%) stated that the varying levels of student understanding was the biggest challenge. Regarding school support for the teaching process, 7% of teachers felt the support was insufficient, 37% considered it adequate, and 56% felt the support provided by the school was very adequate. The challenges of parental involvement and differences in student understanding, identified by teachers as the main obstacles, highlight the importance of collaboration between schools, teachers, and parents in supporting the teaching and learning process. A lack of parental involvement can negatively impact students' academic and social development. The fact that most teachers perceived school support as adequate indicates that the school has provided sufficient assistance, but there is still room for improvement, especially in terms of teacher training, curriculum development, and the use of educational technology. Therefore, learning needs to be directed to prepare students to become adaptive, creative individuals who are able to face complex challenges in an increasingly connected and dynamic society. This means that learning must involve various aspects of educational management, including ongoing support for teachers, parental involvement, and the provision of facilities that are relevant to the needs of education in the modern era (Amelia, 2023 & Aspi, 2022)

Regarding aspects that can be improved to further support the learning process, teachers proposed increasing parental involvement (10%), teacher training (18%), curriculum development (20%), resource or teaching material development (22%), and the use of educational technology (30%). These suggestions reflect teachers' commitment to continuously improving the quality of education and the involvement of all parties in the educational process.

Overall, these results emphasize the need for holistic support for teachers, both in the form of ongoing professional development and the provision of adequate resources, so that they can address various challenges in the teaching process and improve the overall quality of education. This effort will not only enhance teaching effectiveness but also contribute to increasing student readiness and learning outcomes, ultimately supporting the achievement of higher educational goals (Abidin, 2019; Luthfia & Triono Ali Mustofa, 2024; Wicaksono & Iswan, 2019)

Based on the results presented by the researcher above, the development of STEAM-based educational media resulted in a prototype after the stages of need identification and instructional material analysis. The developed media included interactive teaching aids, technology-based applications, and experimental activities integrating elements of science, technology, engineering, arts, and mathematics. This is in accordance with the stages described in the ADDIE development research at the analysis stage (Hidayat & Nizar, 2021)

This prototype was then validated by experts and teachers involved in the lesson study. The initial validation results from experts and teachers involved in the lesson study showed that the STEAM-based learning media prototype had met the eligibility criteria in terms of content, construction, and usability. These findings indicate that the media has the potential to support the learning process in the classroom and facilitate students' understanding of the material being taught, namely the solar eclipse model material in the upper grades, and the sustainable lifestyle material in the lower grades. However, the input obtained during the validation also showed that there were aspects that needed to be improved, such as adding a user guide for students and simplifying the content to make it easier for elementary school students to understand. This is important considering the age and cognitive level of students at the elementary level who require a clear and uncomplicated approach (Bujuri, 2018). The revisions made based on the input were

aimed at optimizing the effectiveness of the media so that it could be used independently by students with minimal guidance from teachers. In addition, content adjustments ensured that the material presented was in accordance with the level of understanding of elementary school students, which was ultimately expected to increase student engagement in learning (Nurrita, 2018). Limited trials conducted in several classes in Cisolok District provided empirical data on the effectiveness and acceptance of the media in the field. Based on the trial results, this media received a positive response from students and teachers, indicating that the media succeeded in attracting students' interest and encouraging them to actively participate in learning. In addition, the teachers involved reported that this media helped clarify the abstract STEAM concept, so that the learning process became more contextual and relevant. However, these findings also revealed several challenges, such as the need for additional assistance in the early stages of media use. This shows that although the media is feasible to implement, the role of teachers in providing initial direction remains important, especially at the beginning of implementation. In the long term, the results of this trial also confirmed that teacher collaboration through lesson study is effective in identifying and improving critical aspects of learning media, which ultimately improves the quality of the media and teacher readiness to use it in the classroom (Nurfadhillah et al., 2021)

Media Implementation in Lesson Study result, STEAM-based educational media was implemented in several lesson study sessions with elementary school teachers in Cisolok Subdistrict. In these activities, teachers collaborated to plan lessons utilizing the media, conduct classroom teaching, and evaluate the outcomes. Observations during the implementation showed that students were highly interested and more engaged in learning using STEAM-based media. For example, when using teaching aids or conducting simple experiments, students appeared more involved and enthusiastic, as reflected in their increased participation in discussions and interest in exploring the presented material. The results show great potential to increase student engagement in classroom learning. The high interest and participation of students during the activity indicate that the STEAM approach can provide a more contextual and relevant learning experience. This is evident, for example, when students are invited to do experiments or use simple props, they appear more enthusiastic and actively participate. Through this interactive learning, students not only hear and observe, but also experience the concept directly, so that they better understand the material being taught (Elfa Sumiyati, 2017). High student engagement also shows that STEAM-based media can function as a bridge to explain concepts that may be abstract or difficult to understand if only delivered verbally. The use of this media encourages students to think critically and creatively, in accordance with the principles of 21st century learning that emphasizes higher-order thinking skills. Their desire to discuss and further explore the material provided shows that this media helps increase students' curiosity, which is an important factor in supporting a more meaningful learning process (Inayah, 2024; Nurbaya et al., 2024; Mubarok et al., 2024). From a teacher's perspective, this implementation provides insight into the importance of collaboration in planning and adapting learning media to student needs. Teachers involved in lesson study felt more prepared and confident in teaching using the STEAM approach after going through this collaborative process. Lesson study also opened up space for teachers to share the best strategies and methods that could be applied, so that the result was media that was not only effective but also practical to use in the classroom. However, although the results of this implementation were very positive, there were still challenges that needed to be overcome. Several teachers expressed the need for additional time to prepare the tools and materials used in STEAM-based media, as well as time

to understand the technicalities of using the tools. This shows that, although this media is effective, further support is needed from the school, such as providing adequate tools and additional training for teachers.

After the lesson study sessions, the teachers conducted a joint reflection on the implementation of the STEAM-based educational media. From these discussions, the teachers stated that the media greatly helped them in teaching complex concepts in a more engaging and easily understandable way for students. Moreover, the teachers found that the integration of disciplines in STEAM encouraged students to think more critically and creatively. According to the research findings, STEAM-based media proved highly effective in improving students' understanding across various disciplines. The combination of elements from STEAM helped students see the connections between concepts and apply them in reallife (Nurbaya et al., 2024). Compared to conventional teaching methods, this media was more capable of attracting students' interest and motivating them to actively engage in the learning process.

Lesson study also played a significant role in the development and implementation of this media. Through teacher collaboration, the planning and reflection process became more focused and productive. Teachers were not only involved in media development but also in identifying learning problems and finding solutions together. Teachers involved in the lesson study felt an increase in professional competence, especially in designing and implementing innovative educational media (M., 2017 & Tedjawati, 2011)

Although the implementation of STEAM-based media through lesson study in Cisolok District showed positive results, several challenges emerged, especially limited resources, such as lack of access to technology and supporting devices in several schools. This challenge is in line with other studies, such as those conducted by (S. Kim & Lee, 2018) which found that STEAM implementation is often hampered by infrastructure limitations, especially in areas with limited access to technology. However, the lesson study approach allows teachers to find collective solutions to overcome these obstacles, for example by adapting STEAM-based media to be simpler and remain contextual for elementary school students, such as the use of materials that are easily found in the surrounding environment as teaching aids. The results of this study provide an important contribution to the development of STEAM-based learning models in elementary schools, especially in Cisolok District, with broader implications for other regions in Indonesia. Through lesson study, teachers not only succeeded in developing innovative media, but also experienced an increase in collaborative and reflective competence in their teaching. This finding strengthens the results of research by (Lewis et al., 2020), which shows that lesson study can enrich teachers' ability to design more adaptive and relevant teaching to students' needs, especially in the context of STEAM-based education. In addition to its benefits, these findings also have several limitations that need to be considered. First, the scope of implementation is limited to one district, so the results may not be fully representative of the wider context. Potential obstacles to implementing this model in other areas could also include differences in school resources, teacher readiness levels, and policy support from local stakeholders. To expand its benefits, further studies are needed in diverse contexts, for example in schools in urban and rural areas that have different challenges and characteristics. The implications of the results of this study for education policy are also worth noting. These results can be the basis for recommendations for policy makers to encourage the implementation of lesson study as one of the methods of teacher professional development, especially in implementing STEAM-based learning. In addition, the development of a curriculum that supports STEAM involvement at the elementary level can be considered so that the process of adapting this method in the field can run more smoothly.

For future research, there are several areas that can be further explored, such as the effectiveness of using STEAM-based media at various school levels or longitudinal studies to measure the long-term impact of lesson study on teacher competency and student learning outcomes. In addition, research on the use of more specific technologies, such as edutainment-based digital tools or virtual simulations, can be conducted to examine how these technologies can be more effectively integrated into the STEAM approach, especially in schools with limited resources. Thus, this study provides a strong foundation for the development and implementation of lesson study and STEAM media that are broader, relevant, and sustainable in the context of education in Indonesia.

Conclusion

The development of STEAM-based learning media through lesson study has not only succeeded in creating innovative learning products or media, but also empowered teachers to develop more creative and collaborative teaching approaches. The results of the implementation in Cisolok District show that the application of STEAM-based media through lesson study strengthens collaboration among teachers and has a positive impact on learning, as evidenced by the increased involvement and enthusiasm of students in class.

However, this study has several limitations that need to be noted. The limited scope of implementation in one district makes the results less representative for other areas with different contexts and challenges. Barriers to wider implementation, such as differences in resource availability in other schools, levels of policy support, and teacher readiness, are also important considerations. Limited technological infrastructure in some schools can limit the sustainability and effectiveness of the STEAM-based media developed.

To enrich these findings, future research can examine the application of similar models in various contexts, such as schools in urban areas or areas with different access to technology. Longitudinal studies can also be conducted to see the long-term impact of the implementation of STEAM media on teacher competence and student learning outcomes. In addition, research on the adaptation of STEAM-based media in schools with limited resources could be an important focus, to produce more inclusive and widely accessible models. Another interesting area to explore is the integration of digital technology and virtual simulation in STEAM-based media, to see how these technologies can support the development of critical and creative thinking skills in students.

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