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RECONCEPTUALIZING MATHEMATICS LEARNING THROUGH STEAM INTEGRATION: A QUALITATIVE PERSPECTIVE

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Abstract

This study explores the reconceptualization of mathematics learning through the integration of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. Using a qualitative descriptive method, the research examines how STEAM-based learning influences students' mathematical understanding, creativity, and 21st-century competencies. Data were collected through in-depth interviews with teachers, classroom observations, and document analysis. The findings reveal that project-based and inquiry-based learning models integrating multiple STEAM disciplines effectively enhance students' mathematical skills. For instance, students engaged in activities such as designing water filtration systems and constructing mathematical models, which required the application of mathematical concepts in real-world contexts. This interdisciplinary approach not only strengthened students' conceptual understanding and problem-solving abilities but also fostered critical thinking, creativity, and collaboration. However, the study also identified several challenges, including limited resources and the need for teachers' professional development in STEAM pedagogy. Despite these constraints, teachers demonstrated adaptability by utilizing available materials and collaborative practices to implement STEAM learning effectively. The study concludes that integrating STEAM into mathematics education can transform traditional learning into a more meaningful and engaging process. It promotes active student participation and supports the development of mathematical, cognitive, and social skills necessary for addressing real-world challenges in the 21st century.

Keywords: *STEAM; Mathematics Learnin; Problem-Solving Skills; Qualitative Study*

Abstrak

Penelitian ini mengkaji rekonseptualisasi pembelajaran matematika melalui integrasi pendekatan STEAM (Sains, Teknologi, Teknik, Seni, dan Matematika). Dengan menggunakan metode deskriptif kualitatif, penelitian ini mengkaji bagaimana pembelajaran berbasis STEAM memengaruhi pemahaman matematika, kreativitas, dan kompetensi abad ke-21 siswa. Data dikumpulkan melalui wawancara mendalam dengan guru, observasi kelas, dan analisis dokumen. Temuan menunjukkan bahwa model pembelajaran berbasis proyek dan berbasis penelusuran yang mengintegrasikan berbagai disiplin ilmu STEAM secara efektif meningkatkan keterampilan matematika siswa. Misalnya, siswa terlibat dalam aktivitas seperti merancang sistem penyaringan air dan membangun model matematika, yang memerlukan penerapan konsep matematika dalam konteks dunia nyata. Pendekatan interdisipliner ini tidak hanya memperkuat pemahaman konseptual dan kemampuan pemecahan masalah siswa, tetapi juga menumbuhkan pemikiran kritis, kreativitas, dan kolaborasi. Namun, studi ini juga mengidentifikasi beberapa tantangan, termasuk keterbatasan sumber daya dan kebutuhan akan pengembangan profesional guru dalam pedagogi STEAM. Terlepas dari kendala-kendala ini, para guru menunjukkan kemampuan beradaptasi dengan memanfaatkan bahan-bahan yang tersedia dan praktik kolaboratif untuk menerapkan pembelajaran STEAM secara efektif. Studi ini menyimpulkan bahwa mengintegrasikan STEAM ke dalam pendidikan matematika dapat mengubah pembelajaran tradisional menjadi proses yang lebih bermakna dan menarik. Hal ini mendorong partisipasi aktif siswa dan mendukung pengembangan keterampilan *matematika, kognitif, dan sosial yang diperlukan untuk mengatasi tantangan dunia nyata di abad ke-21.*

Kata Kunci: STEAM; Pembelajaran Matematika; Keterampilan Memecahkan Masalah; Studi Kualitatif

INTRODUCTION

Education plays a pivotal role in shaping human development. As a fundamental institution in society, schools are expected to provide a comprehensive learning environment that fosters not only intellectual growth but

also emotional and social development. This holistic approach is essential in preparing students to actively participate in society and adapt to rapid global changes. According to Tilaar (2022) and Darmaningtyas (2015), educational practices must align with societal values while addressing the diverse needs of learners. In Indonesia, education is also a constitutional right, ensuring that every citizen has access to quality learning opportunities that support personal and societal advancement (Sutrisno, 2019; Koesoemo, 2007).

In the context of mathematics education, the demand for innovation is increasingly urgent. Traditional mathematics instruction often emphasizes procedural knowledge and rote memorization, limiting students' opportunities to develop deeper conceptual understanding and higher-order thinking skills. As a result, many students struggle to connect mathematical concepts with real-world applications. This gap highlights the need to reconceptualize mathematics learning into a more meaningful, contextual, and student-centered process.

One promising approach is the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics). This interdisciplinary framework promotes the development of critical thinking, creativity, collaboration, and problem-solving skills through real-world learning experiences (Beers, 2011). Rather than treating mathematics as an isolated subject, STEAM positions it as a dynamic and applicable discipline that intersects with other fields of knowledge.

The STEAM approach has gained recognition for its potential to transform mathematics education. By engaging students in project-based and inquiry-based learning, STEAM encourages them to explore mathematical concepts through hands-on activities and authentic problem-solving. For example, students may design simple engineering projects, analyze data, or create models that require mathematical reasoning. These experiences not only strengthen conceptual understanding but also foster creativity and innovation.

In the context of Indonesian primary education, particularly in Madrasah Ibtidaiyah (MI), mathematics learning still tends to rely on conventional teaching methods. These methods often focus on achieving correct answers rather than understanding processes, which can limit students' cognitive development. As Islamic-based educational institutions, MI have a strategic role in developing students' intellectual and moral capacities. Therefore, integrating innovative approaches such as STEAM is essential to support holistic education that combines cognitive, social, and creative development.

Reconceptualizing mathematics learning through STEAM integration offers a meaningful solution to these challenges. By incorporating interdisciplinary elements into mathematics instruction, teachers can create engaging learning environments that connect

abstract concepts to real-life situations. This approach encourages students to actively construct knowledge, collaborate with peers, and develop essential 21st-century skills.

However, implementing STEAM in mathematics classrooms is not without challenges. Teachers may face difficulties in designing interdisciplinary lessons, managing classroom activities, and accessing adequate resources. Additionally, limited training in STEAM pedagogy can hinder effective implementation. Despite these challenges, many educators demonstrate adaptability by utilizing available resources and collaborative strategies.

This study aims to explore how mathematics learning can be reconceptualized through the integration of the STEAM approach. Specifically, it investigates teaching strategies, classroom practices, challenges encountered, and the impact on students' mathematical understanding and skills. By adopting a qualitative perspective, this research seeks to provide in-depth insights into the implementation of STEAM in mathematics education.

The findings of this study are expected to contribute to the development of innovative teaching practices and provide practical recommendations for educators. Ultimately, this research supports the transformation of mathematics learning into a more engaging, meaningful, and relevant process that equips students with the skills needed to face future challenges.

METHOD

This study employs a qualitative descriptive approach to explore the integration of the STEAM approach in mathematics learning. The research focuses on understanding how STEAM-based instruction is implemented and how it influences students' mathematical skills and learning experiences.

The research subjects consist of mathematics teachers and fourth-grade students at a selected Madrasah Ibtidaiyah (MI). Data were collected through in-depth interviews, classroom observations, and document analysis. Interviews were conducted with teachers to examine their perceptions, instructional strategies, and challenges in implementing STEAM-based mathematics learning. Classroom observations were carried out to capture real teaching practices, student engagement, and the integration of STEAM elements during mathematics lessons. Document analysis included lesson plans, teaching materials, and students' work to identify how mathematical concepts were connected with other STEAM disciplines.

Data analysis was conducted using thematic analysis by organizing the data into key themes, such as instructional strategies, student engagement, development of mathematical understanding, and implementation challenges. To ensure the validity and reliability of the findings, triangulation techniques were applied by comparing data obtained from interviews, observations, and document analysis.

RESULTS AND DISCUSSION

RESULT

This study explored the integration of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in reconceptualizing mathematics learning through a qualitative descriptive method. The research aimed to examine how interdisciplinary learning enhances students' mathematical understanding, fosters creativity, and develops 21st-century competencies. Data were collected through classroom observations, semi-structured interviews with teachers and students, and document analysis of lesson plans and students' work. Thematic analysis revealed several key findings related to forms of STEAM integration, its impact on mathematical understanding, student engagement, teacher strategies, and implementation challenges.

Forms of STEAM Integration in Mathematics Learning

The integration of STEAM in mathematics learning was primarily implemented through project-based and inquiry-based approaches. These approaches enabled students to connect mathematical concepts with real-world applications across disciplines.

For instance, students were tasked with designing a simple water filtration system using recycled materials. In this activity, mathematics was applied in measuring volume, estimating proportions, and analyzing efficiency. Similarly, students engaged in designing geometric models and calculating dimensions, which strengthened their understanding of spatial reasoning. These activities demonstrate that mathematics was not taught as an isolated subject but as a tool for solving real-life problems, supporting interdisciplinary learning as emphasized by Yakman (2008).

Impact on Students' Mathematical Understanding

The findings indicate that STEAM-based learning significantly enhanced students' conceptual understanding of mathematics. Students demonstrated improved ability to apply mathematical concepts such as measurement, geometry, and basic data analysis in practical contexts.

For example, when working on projects, students calculated dimensions, interpreted results, and explained their reasoning. This process strengthened their problem-solving skills and conceptual clarity. Rather than relying on memorization, students developed a deeper understanding of mathematical relationships, aligning with constructivist learning principles.

Enhancement of Creativity and Engagement

STEAM-based mathematics learning fostered high levels of student engagement and creativity. Students showed enthusiasm when involved in hands-on activities such as

constructing models, designing projects, and presenting their findings.

One student stated that learning mathematics became easier when applied in real activities, while another expressed greater interest in solving problems through projects rather than traditional exercises. These findings indicate that experiential learning increased motivation and made abstract mathematical concepts more accessible.

Teacher Strategies in Implementing STEAM

Teachers played a crucial role in adapting STEAM learning to classroom conditions. Despite limited resources, teachers utilized locally available materials and collaborative strategies to design meaningful learning experiences.

Teachers also broke down complex projects into manageable steps and integrated mathematical concepts gradually. Peer collaboration among teachers was another important strategy to share ideas and improve instructional practices.

Challenges in STEAM Implementation

Several challenges were identified, including limited resources, lack of training in STEAM pedagogy, and time constraints. Mathematics learning through projects often required more time compared to conventional instruction.

However, teachers addressed these challenges through creativity, flexibility, and collaboration. These findings align with Herro and Quigley (2017), emphasizing the importance of teacher adaptability in implementing innovative learning approaches.

Development of 21st-Century Skills

STEAM integration contributed significantly to the development of students' 21st-century skills. Students demonstrated improvement in: Critical thinking through problem analysis, Creativity through project design, Collaboration through group work , Communication through presentations and explanations

These competencies align with the 4Cs framework and reflect higher-order thinking skills as described in Bloom's Taxonomy.

DISCUSSION

The findings of this study confirm that integrating STEAM into mathematics learning provides a meaningful shift from traditional, procedure-oriented instruction toward a more contextual and student-centered approach. Mathematics is no longer positioned as abstract knowledge but as an applied discipline closely connected to real-world problem-solving.

The use of project-based and inquiry-based learning enables students to construct their understanding actively. This supports constructivist theory, where knowledge is built through experience and interaction. Students' ability to apply mathematical concepts in designing projects demonstrates deeper conceptual understanding rather than surface-level learning.

Furthermore, the study highlights the role of engagement and creativity in mathematics learning. Consistent with Ryan and Deci's Self-Determination Theory (2000), students showed higher motivation when learning activities involved autonomy, meaningful tasks, and collaboration. STEAM activities created an environment where students felt more involved and confident in learning mathematics.

From a sociocultural perspective, Vygotsky's theory is also evident in the findings. Learning occurred through interaction, discussion, and collaboration, allowing students to develop mathematical understanding within their social context. Teacher scaffolding and peer interaction played essential roles in facilitating learning.

Despite these benefits, challenges such as limited resources and lack of training remain significant barriers. However, the adaptability demonstrated by teachers indicates that successful implementation of STEAM does not always require advanced facilities but rather innovative pedagogical approaches.

Overall, this study supports the idea that reconceptualizing mathematics learning through STEAM integration can enhance both cognitive and non-cognitive skills, making learning more relevant and effective.

CONCLUSION

This study concludes that the integration of the STEAM approach plays a significant role in reconceptualizing mathematics learning. It transforms mathematics from a traditionally abstract subject into a meaningful, engaging, and application-oriented discipline. STEAM-based learning enhances students' conceptual understanding, problem-solving skills, creativity, and engagement. In addition, it supports the development of essential 21st-century competencies, including critical thinking, collaboration, and communication. Although challenges such as limited resources, time constraints, and lack of teacher training persist, these obstacles can be addressed through teacher creativity, collaboration, and continuous professional development. The findings suggest that STEAM integration has strong potential to improve the quality of mathematics education, particularly in primary education contexts such as Madrasah Ibtidaiyah.

Future research is recommended to: develop more structured assessment tools for measuring mathematical improvement, explore long-term impacts of STEAM learning, examine the effectiveness of STEAM compared to traditional methods. Ultimately, this study contributes to the growing body of research advocating for innovative, interdisciplinary approaches in education and supports the transformation of mathematics learning to better prepare students for the complexities of the 21st century.

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PROFIL SINGKAT

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