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Exploration of STEAM learning in Nigeria and Indonesia for primary school student

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ABSTRACT

In the era of the industrial revolution 4.0, the STEAM learning approach is very important to form a generation that is not only academically intelligent but also creative, collaborative, and adaptive since elementary school level. However, the implementation of STEAM learning in developing countries such as Nigeria and Indonesia still faces various challenges, ranging from limited resources, teacher readiness, to suboptimal policy support. This study aims to explore in depth the experiences of teachers, the learning strategies applied, and the obstacles they face in implementing the STEAM approach in elementary schools in both countries. This study uses a descriptive qualitative approach with data collection techniques through in-depth interviews with teachers and principals who are actively involved in STEAM learning practices. Data were analyzed using NVivo software to identify key themes that emerged from informant narratives. The results of the study indicate that teachers in Nigeria and Indonesia have begun to implement STEAM contextually with a project-based approach, but its implementation is still limited due to lack of training, limited media and learning aids, and school policies that do not fully support it. In conclusion, the success of STEAM implementation in primary schools is highly dependent on strengthening teacher capacity through ongoing training, provision of learning resources relevant to the local context, and support from an education system that is adaptive to the needs of cross-disciplinary learning in developing countries.

INTRODUCTION

In the era of the industrial revolution 4.0, education is required to produce a generation that is not only academically intelligent, but also creative, collaborative, and adaptive (Whalley et al., 2021; Judijanto & Wardhana, 2025). The STEAM learning approach that includes Science, Technology, Engineering, Arts, and Mathematics is one of the main strategies in realizing this (Belbase et al., 2022; Shatunova et al., 2019). Through the integration of these disciplines, students are encouraged to think critically, solve problems, and appreciate art as part of the learning process. The application of STEAM is very relevant at the Elementary School level because this period is the foundation for the formation of 21st century competencies (Safitri, 2022).

The implementation of STEAM learning in various developing countries faces various challenges. Factors such as education policies, limited resources, and teacher competencies are the main obstacles in its implementation (Aslam et al., 2023; Voicu et al., 2022). Nigeria and Indonesia

are two countries that are committed to improving the quality of basic education through the STEAM approach. In Nigeria, the national education policy has begun to support STEM development since elementary education (Asuquo-Ekpo, 2024). Meanwhile, in Indonesia, the Independent Curriculum provides space for cross-disciplinary approaches and project-based learning (Arwitaningsih et al., 2023). Despite their different socio-cultural backgrounds, both show similarities in challenges and the spirit of innovation.

Initial needs analysis shows that Primary School teachers in Nigeria and Indonesia still need a deep understanding of the concept and application of integrated STEAM learning. A study by Chisom,Unachukwu, & Osawaru (2024) revealed that most teachers in Nigeria have not received adequate training in cross-disciplinary approaches, especially in integrating arts elements into STEM. In Indonesia, research by Rakhmawati et al. (2024) showed that limited resources, learning media, and minimal school policy support are major obstacles to the implementation of STEAM at the elementary level. In addition, teachers still need technical guidance and examples of good practices in order to be able to apply learning that is relevant to the local context of students (Pawartani, et al., 2024). Therefore, this study is needed to map the real needs of teachers and schools as a basis for formulating contextual and sustainable STEAM strategies in both countries.

The urgency of this research is to understand in depth how the STEAM learning approach is applied at the Primary School level in the context of developing countries such as Nigeria and Indonesia. Although the STEAM approach has proven effective in improving 21st century competencies, its implementation in developing countries still faces various challenges, such as limited resources, teacher readiness, and policy support (Deák & Kumar, 2024; González & Ramírez, 2022). This research is important because it can reveal the strategies, good practices, and obstacles faced by both countries in adopting this learning model. Thus, the results of this study are expected to provide academic and practical contributions in the development of contextually relevant educational policies and innovations.

Research on STEAM learning has shown positive impacts on the development of 21st century skills, especially at the primary education level. Kuhn et al (2016) highlighted that the integration of engineering design into science activities encourages students to think critically and creatively. Ng, Kewalramani & Kidman (2022) developed a STEAM framework that emphasizes the importance of interdisciplinary relationships to support contextual learning. In Nigeria, Babaci, Babaci-Wilhite, et al. (2019) identified that the main obstacles to STEAM implementation lie in the lack of teacher training and minimal integration of arts elements. Meanwhile, research by Nuragnia & Usman (2021) in Indonesia showed that the implementation of project-based STEAM can increase active student participation, although its implementation still depends on specific school initiatives. In addition, the study by El Bedewy et al. (2024) emphasized the need for local adaptation of the STEAM model to suit the cultural context and resources in developing countries. Therefore, this study is here to answer the research gap related to the comparison of STEAM practices in Nigeria and Indonesia at the Primary School level more comprehensively.

This study makes an important contribution to broadening the understanding of STEAM learning implementation in developing countries, particularly at the primary school level in Nigeria and Indonesia. Through a comparative approach, this study not only enriches the academic

literature on interdisciplinary education but also offers practical insights for educators and policy makers in designing contextual and sustainable learning strategies. In addition, the results of this study are expected to form the basis for the development of teacher training and curricula that are more responsive to local challenges. Thus, this study contributes to bridging the gap between STEAM theory and practice in the field globally and regionally.

METHOD

1. Types of research

This study uses a qualitative approach because it aims to explore in depth the learning practices (Creswell, 2017). The type of research used is descriptive exploratory, which allows researchers to describe the phenomenon of STEAM implementation naturally and contextually based on the experiences and perceptions of teachers and schools. This approach was chosen so that researchers can gain a rich understanding of the reality of learning in the field, including the constraints, strategies, and potentials of each country. This study does not focus on measuring numbers, but rather on the meaning, narrative, and interpretation that emerges from qualitative data.

2. Techniques and Instruments Data collection

The data collection technique in this study was carried out through in-depth interviews with three main informants from two countries, namely Nigeria and Indonesia. The informants consisted of two elementary school teachers and one principal who were selected purposively based on their active involvement in the implementation or understanding of STEAM learning. The interviews were conducted in a semi-structured manner, allowing researchers to flexibly explore the experiences, understandings, challenges, and strategies of the informants in implementing STEAM learning in their respective school environments. Data from these interviews were recorded, transcribed, and analyzed to obtain an in-depth picture of the actual conditions of STEAM implementation in both countries. The following is the interview guideline instrument presented in Table 1.

Table 1. Interview Guidelines Grid

No.	Aspect	Indicator
1	STEAM implementation experience	- Using STEAM learning methods - Examples of STEAM learning activities in the classroom
2	Learning strategies	- How to integrate science, technology, engineering, arts, and mathematics - Use of media and teaching aids
3	Obstacles or barriers	- Technical and non-technical obstacles in implementing STEAM - Obstacles from students or the environment

3. Data Analysis Techniques

The data obtained from the interview results were then analyzed qualitatively using NVivo software to facilitate the process of managing and coding data. The analysis process began with a complete transcription of the interview, then the data was coded based on the themes that emerged according to the aspects of the study. NVivo helps in organizing data systematically so that researchers can identify patterns, categories, and relationships between themes more effectively.

The results of this analysis are used to describe in depth the implementation of STEAM learning as well as the challenges and needs faced by teachers and schools in Nigeria and Indonesia.

RESULTS

1. NVivo Word Tree from STEAM Words

To gain a deeper understanding of the context of the use of the word STEAM in the interview data, the researcher used the Word Tree feature of the NVivo software. This visualization helps identify recurring thematic patterns in relation to the implementation of STEAM learning in primary schools, both in Nigeria and Indonesia. This Word Tree shows how the word STEAM is used in various contexts, such as teacher experiences, learning strategies, technical barriers, and project-based approaches. Thus, this visualization not only clarifies the main focus of the study but also strengthens the findings obtained from the previous thematic analysis. The following is Figure 1 of the NVivo visualization results of the STEAM word network.

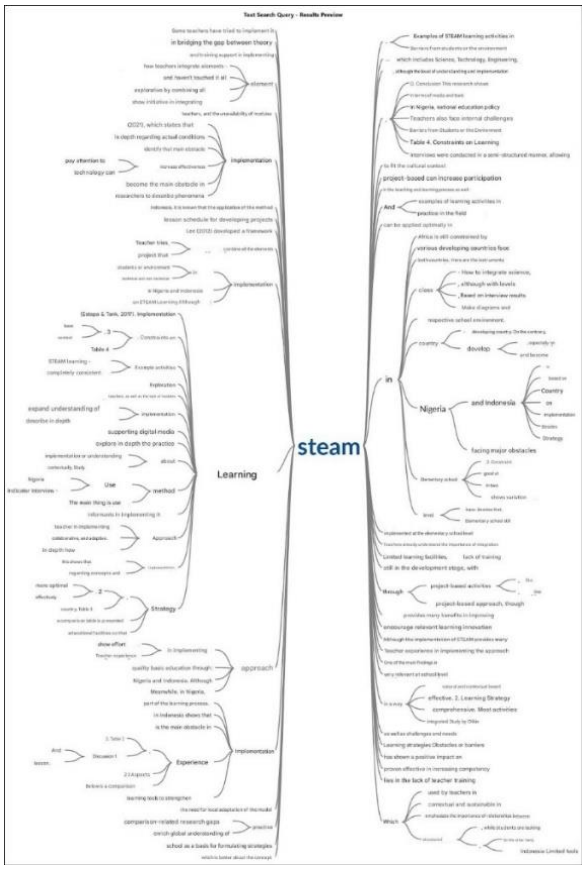

Figure 1. Word Tree of the word "STEAM"

The NVivo Word Tree of the word STEAM shows the various contexts of implementation and challenges of STEAM learning in primary schools, specifically in Nigeria and Indonesia. The visualization links the word STEAM to themes such as teacher experiences, instructional strategies, technical barriers, and project-based approaches. Phrases such as "project-based activities," "expand understanding," "limited learning facilities," and "lack of training" highlight the main focus of the study, which is the exploration of STEAM practices in the primary education context of developing countries. These word trees indicate that the integration of Science, Technology, Engineering, Arts, and Mathematics elements is still in its infancy, and requires

support from teacher training, learning media, and policy adaptations to be implemented contextually and sustainably.

2. STEAM Implementation Experience

One of the main findings in this study is the experience of teachers in implementing the STEAM learning approach in the classroom. Based on the results of in-depth interviews with informants from Nigeria and Indonesia, it is known that the implementation of the STEAM method at the Elementary School level is still diverse, both in terms of understanding the concept and its implementation practices. Differences in social context, education policies, and resource readiness affect the extent to which teachers are able to integrate elements of Science, Technology, Engineering, Arts, and Mathematics in the learning process.

To clarify the findings, the following presents a comparison of the experience of implementing STEAM in Nigeria and Indonesia based on two main indicators, namely the use of STEAM learning methods and examples of classroom learning activities in Table 2.

Table 2. Experience STEAM implementation in Nigeria and Indonesia

Country	Using STEAM Learning Methods	Examples of STEAM Learning Activities in Class
Nigeria	Teachers already understand the importance of integrating science and mathematics, but implementation is still limited and not yet systematic.	Creating diagrams and calculations in simple science projects, but without explicitly integrating art elements.
Indonesia	Some teachers have tried to implement STEAM through a project-based approach, although not yet completely consistently.	Students make a bridge from ice cream sticks (Engineering), calculate the weight of the load (Math), record observations (Science), and draw it (Art).

Table 2 illustrates that both Nigerian and Indonesian teachers have demonstrated efforts in implementing STEAM approaches in the classroom, albeit at varying levels. In Indonesia, some teachers have begun to explore the integration of science, technology, engineering, arts, and mathematics elements through contextual project-based activities. Meanwhile, in Nigeria, the STEAM approach is still in its infancy, with an initial emphasis on strengthening STEM elements. Both contexts demonstrate the potential and commitment to developing cross-disciplinary learning, along with the need for more optimal training and resource development support.

3. STEAM Learning Strategies in Nigeria and Indonesia

In addition to implementation experiences, the learning strategies used by teachers in Nigeria and Indonesia are an important focus of this study. These strategies reflect how teachers integrate STEAM elements into the teaching and learning process and the extent to which they utilize the media and teaching aids available in their respective school environments.

Through in-depth interviews, it was found that there were variations in the integrative approaches applied by teachers, depending on conceptual understanding, availability of resources, and creativity in processing learning materials. To illustrate these findings in a more structured

way, the following is a comparative table of STEAM learning strategies used by teachers in both countries.

Table 3. STEAM learning strategies in Nigeria and Indonesia

Country	How to Integrate Science, Technology, Engineering, Arts, and Math	Use of Media and Teaching Aids
Nigeria	Integration is done gradually, starting from combining science and mathematics in simple projects. Art is introduced through drawing activities or explaining concepts.	Using simple aids, such as pictures, whiteboards, and simple practice tools. Digital technology has not been widely utilized.
Indonesia	Teachers try to incorporate all elements of STEAM through project-based activities, such as creating functional works that combine experimentation and artistic creativity.	Using recycled materials, simple experimental tools, and visual media. Some teachers are starting to utilize digital tools such as learning videos.

Table 3 shows that both teachers in Nigeria and Indonesia have developed learning strategies that are tailored to the conditions and resources they have. In Nigeria, interdisciplinary integration is done gradually, with an initial focus on science and mathematics, and the introduction of art through simple activities. Meanwhile, teachers in Indonesia tend to be more explorative in implementing a project-based approach that combines all elements of STEAM.

In terms of media and teaching aids, teachers in both countries showed creativity in utilizing existing resources. In Indonesia, the use of recycled goods and digital technology such as learning videos has begun to be implemented, while in Nigeria, conventional aids such as pictures and whiteboards are still the mainstay. These results reflect the importance of continuous training and support for educational facilities so that STEAM learning strategies can be optimally implemented in various contexts.

4. Barriers to STEAM Learning

Although the implementation of STEAM provides many benefits in improving the quality of learning, in practice there are various obstacles that hinder its implementation. The following table presents an overview of technical and non-technical obstacles as well as obstacles from students and the environment in Nigeria and Indonesia that need to be considered to improve the effectiveness of STEAM implementation.

Table 4. Barriers to STEAM Learning in Nigeria and Indonesia

Country	Technical and Non-Technical Obstacles in STEAM Implementation	Barriers from Students or the Environment
Nigeria	Limited learning facilities, lack of teacher training, and the unavailability of structured STEAM modules.	Students are less accustomed to cross-disciplinary approaches; support from parents and the community for new approaches is still limited.
Indonesia	Limited teaching aids, digital media, and time in the lesson schedule to develop STEAM projects.	Some students have difficulty understanding complex material; the school environment does not fully support cross-subject collaboration.

Table 4 illustrates the technical and non-technical constraints and barriers from students or the environment in implementing STEAM in Nigeria and Indonesia. In Nigeria, the main constraints include limited learning facilities, lack of teacher training, and the unavailability of

structured STEAM modules, while students are less accustomed to the cross-disciplinary approach and support from parents and the community for this new method is still limited. Meanwhile, in Indonesia, limited teaching aids, digital media, and time in the lesson schedule are technical challenges, while barriers from students include difficulty in understanding complex material and a school environment that does not fully support cross-subject collaboration.

DISCUSSION

1. STEAM Implementation Experience

Teachers' experiences in implementing STEAM approaches in primary schools show variations influenced by the social and educational contexts of each country. In Nigeria, teachers have understood the importance of integrating science and mathematics, but the implementation is still limited and has not fully addressed all elements of STEAM. Most activities focus on simple projects that do not explicitly involve elements of art or technology. Research by Nemani (2025), and Belbase et al (2022) shows that limited resources and training are major obstacles to the implementation of STEAM in developing countries.

In contrast, in Indonesia, teachers have begun to explore project-based approaches by combining elements of engineering, art, and mathematics in learning activities. Although the implementation is not yet consistent across schools, examples of practices such as building bridges from popsicle sticks show the potential for cross-disciplinary integration. Teachers' better understanding of STEAM concepts encourages learning innovations that are relevant to students' real lives. This finding is in line with research by Ouafa (2025), Wanyi, Nor & Zhengan (2022), and Spyropoulou & Kameas (2023) who emphasizes the importance of a holistic approach and training support in implementing STEAM effectively.

2. STEAM Learning Strategies in Nigeria and Indonesia

The learning strategies implemented by teachers in Nigeria tend to be gradual, starting with the integration of science and mathematics in simple projects. The limited availability of teaching aids makes teachers rely more on conventional media such as whiteboards and pictures. Although art has begun to be introduced, technological elements are still not optimally utilized due to limited digital infrastructure. This is reinforced by the findings of Ayanwale et al., (2024), and Tang et al. (2025), which state that the implementation of STEAM in Africa is still hampered by the lack of teacher training and minimal technological support.

Meanwhile, teachers in Indonesia show a more explorative approach by combining all elements of STEAM through project-based activities. The use of recycled materials, simple experiments, and digital media are starting to be implemented to increase student engagement. This initiative reflects a shift towards contextual learning that emphasizes collaboration and creativity. This strategy is in line with the research results of Li et al. (2022), Hawari & Noor (2020), and Chistyakov et al. (2023) which suggest that a project-based approach and the use of technology can increase the effectiveness of STEAM implementation in elementary schools.

3. Barriers to STEAM Learning in Nigeria and Indonesia

The implementation of STEAM in Nigeria faces major obstacles in the form of limited learning facilities, lack of teacher training, and the unavailability of structured learning modules. Teachers have difficulty in designing cross-disciplinary learning due to the lack of references and technical support. In addition, students are less accustomed to collaborative approaches, and parental support for new learning methods is still low. These obstacles are in accordance with the findings of Mlambo, Silen & McGrath (2021), Rudnicka et al. (2020), and Kumar et al. (2021) who emphasize the importance of policy interventions and continuous training in developing countries.

In Indonesia, the main obstacles lie in the limited time in the lesson schedule and the lack of teaching aids and digital media that support STEAM learning. Teachers also face challenges in explaining complex concepts to students with diverse abilities. In addition, the school environment does not fully support collaboration between subjects, which is key to cross-disciplinary learning. These findings are in line with research by Boice et al. (2022), Silva-Hormazábal & Alsina (2023), and Gavari et al. (2022) who highlighted the need for synergy between school management, teacher training, and provision of learning facilities to strengthen the implementation of STEAM.

CONCLUSION

This study shows that the implementation of STEAM learning in primary schools in both Nigeria and Indonesia is still in the development stage and faces its own contextual challenges. Teachers in both countries have shown initiative in integrating STEAM elements, although the level of understanding and implementation is uneven. The strategies used reflect teachers' adaptability to resource constraints, with a project-based approach starting to be creatively implemented in some schools. This shows a commitment to providing collaborative and contextual learning, although it still requires stronger systemic support. The main obstacles faced include limited facilities, lack of teacher training, and the lack of structured STEAM learning modules. On the other hand, the learning environment and student readiness are also factors that influence the effectiveness of implementation. Therefore, there is a need for deeper education policy interventions and the development of teacher training based on local needs. This study has an important impact in enriching the global understanding of STEAM practices in developing countries and becoming the basis for formulating more contextual and applicable policies.

REFERENCES

Arwitaningsih, R. P., Dewi, B. F., Rahmawati, E. M., & Khuriyah, K. (2023). Konsep dan implementasi kurikulum merdeka pada ranah rumpun mata pelajaran pendidikan Islam di Sekolah Dasar Islam Terpadu Al Hadi Mojolaban Sukoharjo. *MODELING: Jurnal Program Studi PGMI*, *10*(2), 450-468.

Aslam, S., Alghamdi, A. A., Abid, N., & Kumar, T. (2023). Challenges in implementing STEM education: Insights from novice STEM teachers in developing countries. *Sustainability*, *15*(19), 14455.

Asuquo-Ekpo, B. (2024). Remodelling Education for Students in Nigeria By Providing Relevant Science, Technology, Engineering, and Mathematics Learning (STEM): A Progress Evaluation of SUBEB Teacher Training and After School Initiative, Cross River State. *Open Journal of Educational Development (ISSN: 2734-2050)*, *5*(1), 10-18.

Ayanwale, M. A., Adelana, O. P., & Odufuwa, T. T. (2024). Exploring STEAM teachers' trust in AI-based educational technologies: A structural equation modelling approach. *Discover education*, *3*(1), 44.

Babaci-Wilhite, Z., Babaci-Wilhite, & Liu. (2019). *Promoting language and STEAM as human rights in education*. springer singapore.

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., & Jarrah, A. (2022). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, *53*(11), 2919-2955.

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., & Jarrah, A. (2022). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, *53*(11), 2919-2955.

Boice, K. L., Jackson, J. R., Alemdar, M., Rao, A. E., Grossman, S., & Usselman, M. (2021). Supporting teachers on their STEAM journey: A collaborative STEAM teacher training program. *Education Sciences*, *11*(3), 105.

Chisom, O. N., Unachukwu, C. C., & Osawaru, B. (2024). STEM education advancements in African contexts: A comprehensive review. *World Journal of Advanced Research and Reviews*, *21*(1), 145-160.

Chistyakov, A. A., Zhdanov, S. P., Avdeeva, E. L., Dyadichenko, E. A., Kunitsyna, M. L., & Yagudina, R. I. (2023). Exploring the characteristics and effectiveness of project-based learning for science and STEAM education. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(5), em2256.

Creswell, John W. 2017. *Pendekatan* Metode *Kualitatif*, Kuantittatif dan. Campuran. Yogya: *Pustaka* Pelajar.

Deák, C., & Kumar, B. (2024). A systematic review of STEAM education's role in nurturing digital competencies for sustainable innovations. *Education Sciences*, *14*(3), 226.

El Bedewy, S., Lyublinskaya, I., & Lavicza, Z. (2024). Supporting transdisciplinary STEAM practices: Integrating architectural modelling into mathematics education through a cross-cultural dynamic lesson plan (DLP) tool. *Research and Practice in Technology Enhanced Learning*, *20*(8).

Gavari-Starkie, E., Espinosa-Gutiérrez, P. T., & Lucini-Baquero, C. (2022). Sustainability through STEM and STEAM Education Creating Links with the Land for the Improvement of the Rural World. *Land*, *11*(10), 1869.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, *14*(3), 1493.

Hawari, A. D. M., & Noor, A. I. M. (2020). Project based learning pedagogical design in STEAM art education. *Asian Journal of University Education*, *16*(3), 102-111.

Judijanto, L., Ili, L., & Wardhana, M. G. (2025). Education 5.0: Collaboration and Creativity in Improving Students'digital Intelligence. *International Journal of Teaching and Learning*, *3*(4), 369-382.

Kuhn, M. A., Greenhalgh, S., & McDermott, M. (2016). Using creativity from art and engineering to engage students in science. *Journal of STEM Arts, Crafts, and Constructions*, *1*(2), 2.

Kumar, R., Verma, A., Shome, A., Sinha, R., Sinha, S., Jha, P. K & Vara Prasad, P. V. (2021). Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. *Sustainability*, *13*(17), 9963.

Li, J., Luo, H., Zhao, L., Zhu, M., Ma, L., & Liao, X. (2022). Promoting STEAM education in primary school through cooperative teaching: A design-based research study. *Sustainability*, *14*(16), 10333.

Mlambo, M., Silén, C., & McGrath, C. (2021). Lifelong learning and nurses' continuing professional development, a metasynthesis of the literature. *BMC nursing*, *20*, 1-13.

Nemani, S. (2025). Barriers and Enablers to Adopting Virtual Reality in Lower Secondary STEAM Curricula. *Journal of Advanced Research in Education*, *4*(2), 1-14.

Ng, A., Kewalramani, S., & Kidman, G. (2022). Integrating and navigating STEAM (inSTEAM) in early childhood education: An integrative review and inSTEAM conceptual framework. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(7), em2133.

Nuragnia, B., & Usman, H. (2021). Pembelajaran STEAM di sekolah dasar: Implementasi dan tantangan. *Jurnal Pendidikan Dan Kebudayaan*, *6*(2), 187-197.

Ouafa, O. (2025). Holistic Curriculum Design: Embedding STEAM Principles in Education. In *Transformative Approaches to STEAM Integration in Modern Education* (pp. 529-554). IGI Global Scientific Publishing.

Pawartani, T., & Suciptaningsih, O. A. (2024). Pengembangan kompetensi guru untuk mendukung implementasi kurikulum merdeka. *JIIP-Jurnal Ilmiah Ilmu Pendidikan*, *7*(3), 2182-2191.

Rakhmawati, E., Riniati, W. O., Badriyah, B., & Irmawati, I. (2024). Implementasi Pembelajaran STEAM pada Kelas Rendah di Sekolah Dasar. *Al-Madrasah: Jurnal Ilmiah Pendidikan Madrasah Ibtidaiyah*, *8*(1), 127-133.

Rudnicka, E., Napierała, P., Podfigurna, A., Męczekalski, B., Smolarczyk, R., & Grymowicz, M. (2020). The World Health Organization (WHO) approach to healthy ageing. *Maturitas*, *139*, 6-11.

Safitri, N. A. (2022). The steam approach to improve 21st century skills in elementary schools. *Kalam Cendekia: Jurnal Ilmiah Kependidikan*, *10*(2), 227-233.

Shatunova, O., Anisimova, T., Sabirova, F., & Kalimullina, O. (2019). STEAM as an innovative educational technology. *Journal of Social Studies Education Research*, *10*(2), 131-144.

Silva-Hormazábal, M., & Alsina, Á. (2023). Exploring the impact of integrated STEAM education in early childhood and primary education teachers. *Education Sciences*, *13*(8), 842.

Spyropoulou, N., & Kameas, A. (2023). Augmenting the impact of STEAM education by developing a competence framework for STEAM educators for effective teaching and learning. *Education Sciences*, *14*(1), 25.

Tang, M., Wijaya, T. T., Li, X., Cao, Y., & Yu, Q. (2025). Exploring the determinants of mathematics teachers' willingness to implement STEAM education using structural equation modeling. *Scientific Reports*, *15*(1), 6304.

Voicu, C. D., Ampartzaki, M., Dogan, Z. Y., & Kalogiannakis, M. (2022). STEAM implementation in preschool and primary school education: Experiences from six countries. In *Early Childhood Education-Innovative Pedagogical Approaches in the Post-Modern Era*. IntechOpen.

Wanyi, P., Nor, M. M., & Zhengan, M. (2022). The use of steam approach in preschool for children's holistic development. *JuKu: Jurnal Kurikulum & Pengajaran Asia Pasifik*, *10*(2), 47-60.

Whalley, B., France, D., Park, J., Mauchline, A., & Welsh, K. (2021). Towards flexible personalized learning and the future educational system in the fourth industrial revolution in the wake of Covid-19. *Higher Education Pedagogies*, *6*(1), 79-99.