Elementary School Teacher Education Lecturers' Perception of Science Technology Engineering Arts and Mathematics (STEAM) in Elementary Science Learning

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ABSTRAK

Pembelajaran berbasis STEAM dipandang sebagai pendekatan strategis dalam pendidikan dasar untuk mendorong kemampuan berpikir kritis, kreativitas, dan pemecahan masalah. Namun, keberhasilan penerapannya sangat dipengaruhi oleh persepsi dan kesiapan pendidik sebagai pelaksana utama. Penelitian bertujuan menganalisis persepsi dosen PGSD terhadap pengetahuan, sikap, dan kesiapan mereka dalam mengintegrasikan STEAM pada pembelajaran IPA, termasuk kendala berkaitan dengan keterbatasan fasilitas pendukung. Penelitian ini berpendekatan kualitatif deskriptif dengan melibatkan enam dosen tetap sebagai subjek penelitian. Data diperoleh melalui wawancara mendalam menggunakan pedoman yang menyoroti aspek pengetahuan, sikap, dan kesiapan implementatif STEAM, dianalisis secara tematik. Hasil penelitian menunjukkan para dosen memiliki pemahaman yang baik mengenai konsep STEAM, relevansinya dengan Revolusi Industri 5.0, serta kontribusinya terhadap pengembangan kurikulum. Dari aspek sikap, seluruh dosen menunjukkan pandangan positif dan kesiapan konseptual untuk menerapkan STEAM sebagai sarana penguatan keterampilan abad ke-21. Namun, implementasi di lapangan masih terbatas akibat minimnya fasilitas pendukung dan dukungan institusional. Kesimpulannya yaitu persepsi dosen terhadap STEAM berkategori positif, tetapi implementasinya perlu dukungan yang lebih kuat. Implikasinya, institusi perlu menyediakan fasilitas pembelajaran yang memadai, memperluas pelatihan profesional bagi dosen, serta merancang kebijakan internal yang mendorong integrasi STEAM secara sistematis agar pembelajaran IPA dapat berlangsung lebih efektif, inovatif, dan berkelanjutan.

ABSTRACT

STEAM based learning is viewed as a strategic approach in elementary education for fostering critical thinking, creativity, and problem-solving skills. However, its successful implementation is strongly influenced by educators' perceptions and readiness as key instructional agents. This study aims to analyze PGSD lecturers' perceptions regarding their knowledge, attitudes, and readiness to integrate STEAM into science learning, including constraints related to limited supporting facilities. A descriptive qualitative approach was employed, involving six permanent lecturers as research participants. Data were collected through in-depth interviews guided by an instrument that highlights aspects of STEAM-related knowledge, attitudes, and implementation readiness, and subsequently analyzed thematically. The findings indicate that the lecturers possess a solid understanding of STEAM concepts, its relevance to the Industrial Revolution 5.0, and its contribution to curriculum development. In terms of attitudes, all lecturers demonstrated positive views and conceptual readiness to implement STEAM as a means of strengthening 21st century skills. However, implementation in practice remains limited due to inadequate supporting facilities and insufficient institutional support. This study concludes that lecturers' perceptions of STEAM fall within a positive category, although its implementation requires stronger reinforcement. The implications highlight the need for institutions to provide adequate learning facilities, expand professional development opportunities for lecturers, and design internal policies that systematically promote the integration of STEAM so that science learning can be carried out more effectively, innovatively, and sustainably.

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1. INTRODUCTION

The development of industry, often referred to as the Fourth and Fifth Industrial Revolutions, has driven progress across various sectors, including education (Shahroom & Hussin, 2018). One educational approach derived from this industrial development is STEM (Science, Technology, Engineering, and Mathematics). STEM is a learning approach that integrates multiple disciplines, providing students the opportunity to explore science-based ideas through practical, technical, and technological design experiences within problem-based learning contexts (Nurhikmayati, 2019; Prastika et al., 2022). Moreover, STEM is considered a student-centered and life-relevant learning approach (Broggy et al., 2017). Initially, STEM was primarily applied and studied at the secondary education level. However, the importance of introducing STEM competencies from an early age to prepare students for global industrial competition has been emphasized. Previous studies have also shown that elementary school students are relatively prepared and capable of engaging in STEM-based learning, as science and mathematics are already familiar subjects (Panggarra & Trivena, 2021).

The STEM approach has evolved into STEAM with the integration of the arts, highlighting the importance of creativity, design thinking, and artistic expression in fostering holistic development, particularly among early childhood and elementary students in the context of advancing science, technology, engineering, and mathematics (Henriksen, 2014; Yakman & Lee, 2019). Art practices within STEAM have been shown to foster student independence, responsibility, and problem-solving abilities, and engineering based activities in the classroom can encourage kindergarten students to engage in STEAM practices and explore their emerging identities (Hachey et al., 2022; Rolling, 2016). Furthermore, STEAM learning at the early childhood level can develop critical thinking and problem-solving skills (Debora & Pramono, 2021). Implementing STEAM at the elementary education level requires professional, creative, innovative, and critical teachers who can adapt this approach to the developmental stages of students (Pramudyani & Indratno, 2022). Previous studies involving Elementary School Teacher Education (PGSD) students found that their perceptions of STEAM were generally positive regarding attitudes, opinions, and learning environments (T. Trivena & Langi, 2021). These perceptions are influenced by their environment, particularly their lecturers. As future elementary school teachers, students need lecturers who demonstrate understanding, positive attitudes, and the ability to integrate STEAM into the learning process, especially in STEAM related subjects like Basic Science Learning, to ensure graduates are prepared to face global challenges. Students have also stated that their understanding of STEAM is significantly influenced by the courses delivered by lecturers, which they consider crucial for their future careers. Additionally, STEAM has become an important topic in curriculum development initiatives led by HD PGSDI (Indonesian Association of Elementary Teacher Education), serving as a recommendation for the national PGSD curriculum design. Ultimately, graduates are expected to master 21st-century skills, known as the 4Cs (critical thinking, collaboration, communication, and creativity), which have since evolved into 6Cs with the inclusion of computational logic and compassion, to compete in the global era and Industrial Revolution 5.0 (Fikri et al., 2020).

However, preliminary observations show that STEAM has not yet been fully integrated into the Semester Learning Plans (RPS) for relevant courses, particularly in Basic Science Learning. This indicates a gap between ideal lecturer competencies and current educational needs. While several studies have focused on student perceptions of STEAM, there is a lack of research specifically examining the perspectives of PGSD lecturers, who play a key role in preparing future elementary school teachers and in the development and implementation of curriculum. This study aims to analyze the perceptions of PGSD lecturers regarding the STEAM approach, particularly in terms of their understanding, attitudes, and readiness to implement STEAM based learning in Basic Science Learning. The findings of this research are expected to provide insights for the development of adaptive instructional designs and curricula aligned with the demands of the Industrial Revolution 5.0. Furthermore, the study aims to offer insights for academic programs in developing STEAM based content that can be incorporated into Course Learning Outcomes (CPMK) or instructional designs of courses closely related to STEAM, particularly Basic Science Learning courses.

This research presents novelty in examining the application of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in Basic Science Learning at the elementary education level, focusing on the integration of the arts into science and technology education. While STEAM has been widely implemented in various countries, its application in the Indonesian elementary education curriculum, particularly in science subjects, remains limited and underexplored. This study makes a significant contribution by exploring how the integration of the arts can foster creativity, critical thinking skills, and problem-solving abilities in students, while providing new insights into the readiness of lecturers to implement STEAM in the context of elementary education. Additionally, the research uncovers the perceptions of PGSD lecturers regarding the STEAM approach, which can serve as a reference for the future development of teacher education curricula.

2. METHOD

The research method used in this study is qualitative with a descriptive design. This approach was chosen to explore phenomena, conditions, and contextual factors that are not directly related to measurable variables or experimental interventions. The research findings are presented narratively and interpretively to capture the depth and complexity of participants' perceptions (Creswell, 2016). This study investigates lecturers' perceptions of STEAM without providing any prior treatment to the research subjects, who also serve as key informants. Participant selection was carried out using purposive sampling, a non-random technique in which participants are selected based on specific criteria. A total of six lecturers were selected based on the following criteria: (1) permanent lecturers of the Primary School Teacher Education (PGSD) study program at UKI Toraja, (2) holding at least a Master's degree (S2), (3) having more than two years of teaching experience, and (4) having taught the Elementary Science Education course. This approach allows the researcher to obtain relevant and in-depth data from individuals who have expertise in the topic being studied. The research was conducted in several stages. The first stage involved an initial observation of the Semester Learning Plan (RPS) for the Elementary Science Education course. The second stage was data collection, which included document analysis and in-depth interviews. Observations were conducted on the lecturers' RPS documents to identify the extent to which STEAM based elements were integrated into the course. Baseline data were collected through semi-structured interviews consisting of 15 questions covering three main indicators of lecturers' perceptions of STEAM (1) lecturers' knowledge of the Industrial Revolution 5.0, (2) their attitudes toward the STEAM approach in teaching, and (3) their responses regarding the availability of STEAM-supporting facilities. The indicators of the perception framework for lecturers regarding STEAM integration in elementary science education are presented in Table 1.

Table 1. Framework of Lecturer Perceptions on the Integration of STEAM in Elementary Science Education

No	Aspect	Description	Number of Questions
1	Knowledge	Explores the extent of lectures' understanding of STEAM's core concepts, interdisciplinary integration in learning, and its relation to the Industrial Revolution 5.0.	4
2	Attitude	Reveals lecturers' views and emotional responses toward the STEAM approach, including interest, commitment, and perceived benefits.	7
3	Facilities	Assesses lecturers' responses regarding infrastructure, technology, and learning environments that support STEAM implementation.	4

The third stage involves data processing using qualitative thematic analysis techniques, aiming to identify, organize, and discover patterns (themes) from the collected interview data. The data analysis process begins by filtering information relevant to the research focus. This is followed by coding key data segments that convey specific meanings, which are then grouped into the three main aspects of lecturers' perceptions. Subsequently, conclusions and interpretations are drawn descriptively to address the research focus and objectives, with the goal of deeply understanding the meaning behind each aspect of perception expressed by the informants in a systematic and objective manner. The fourth stage involves compiling the research report and disseminating the findings through publication.

3. RESULT AND DISCUSSION

Result

The instrument used to explore the perceptions of PGSD lecturers at UKI Toraja regarding STEAM was an interview guide consisting of 15 questions administered to 6 informants, all of whom were lecturers in the PGSD study program. The indicators used to develop the interview instrument were aimed at understanding the lecturers' perceptions in terms of: (1) knowledge about the Industrial Revolution 5.0, (2) attitudes toward STEAM, and (3) responses to supporting facilities related to STEAM-based learning in the Elementary Science Education course. The first aspect included four questions designed to assess the lecturers' knowledge regarding the Industrial Revolution 5.0. The summary of PGSD lecturers' perceptions regarding knowledge of the Industrial Revolution 5.0 is presented in Table 2.

Table 2. Summary of PGSD Lecturers' Perceptions in Terms of Knowledge on the Industrial Revolution 5.0

No	Response Perceptions
1.	Several lecturers indicated that they had previously been exposed to information regarding the Industrial Revolution 5.0.
2.	The majority of lecturers demonstrate insufficient comprehension regarding the implications of the Industrial Revolution 5.0 for the realm of higher education.
3.	Lecturers have previously attended training related to the Industrial Revolution 5.0; however, they have not participated in any training specifically focused on the integration of STEAM in learning.
4.	The training attended provided valuable insights and knowledge regarding the Industrial Revolution 5.0; however, it was deemed insufficient due to the absence of follow-up actions or continued support.

Based on Table 2, it is shown that although several lecturers have acquired initial knowledge about the Industrial Revolution 5.0 through training or other sources of information, their understanding of its implementation and impact on education remains limited, particularly in relation to STEAM based learning. The second aspect consists of eight questions used to assess the lecturers' perceptions in terms of their attitudes toward STEAM. The summary of PGSD lecturers' perceptions in terms of attitudes toward STEAM is presented in Table 3.

Table 3. Summary of PGSD Lecturers' Perceptions in Terms of Attitudes Toward STEAM

No.	Response Perceptions
1.	Highly interested in education in the field of STEAM.
2.	STEAM courses are highly beneficial for developing students' creativity and problem-solving skills, particularly in facing the challenges of the 21st century.
3.	The role of lecturers is crucial in fostering students' interest in learning within the STEAM field.
4.	Critical thinking, creativity, and problem-solving skills are essential competencies that students need to develop in order to face future challenges.
5.	The main factor contributing to students' lack of interest in STEAM related courses is their unclear understanding of the student development trajectory within STEAM based learning.
6.	Courses in the field of STEAM are considered priority courses within the study program.
7.	The challenges in integrating STEAM into the PGSD curriculum include a lack of qualified lecturers, insufficient facilities/equipment, limited time, and budget constraints.

Based on Table 3, the results overall indicate a positive attitude and high enthusiasm among lecturers regarding the implementation of STEAM. They acknowledge the strategic value of STEAM in equipping students with 21st-century skills and consider it a curricular priority. However, lecturers also highlighted several structural and operational challenges, such as the lack of trained human resources, inadequate facilities, limited time, and funding constraints. In addition, they emphasized the need for a clearer explanation of the STEAM learning process for students. These findings underscore the importance of strengthening lecturer capacity, providing adequate facilities, and developing a more integrated curriculum plan so that this positive attitude can be optimally implemented in classroom practices, particularly in elementary science education. The third aspect concerns the facilities that support STEAM based science learning. The summary of lecturers' perceptions regarding the availability of STEAM supportive facilities in the study program is presented in Table 4.

Table 4. Summary of PGSD Lecturers' Perceptions of Facilities Supporting STEAM-Based Learning

No.	Response Perceptions
1.	The lecturers stated that there are no specific activities, classes, or courses such as mathematics, science, or computer tutorials provided separately. However, the courses taken by students already include subjects related to Mathematics, Science, and Computer Studies.
2.	Few students participate in Mathematics and Science Olympiads.
3.	The study program does not specifically organize field visits or science exhibitions. However, the university has previously conducted study tours to prominent universities, although the objective was not specifically aimed at exploring science.
4.	Only science and mathematics kits are available to support coursework related to science and mathematics subjects, along with a general Physics Laboratory and a general-purpose Computer Laboratory.

Based on Table 4, that although STEAM elements such as Science, Mathematics, and ICT are already included in subject specific courses like Science and Mathematics, the supporting facilities and programs remain limited and are not yet specifically integrated to support the STEAM approach. This indicates that efforts to strengthen STEAM based learning still require improvements in infrastructure, extracurricular program support, and the use of more contextualized learning approaches.

Discussions

Educators' perceptions in the learning process are an important factor in effectively integrating content knowledge and pedagogical approaches. Their beliefs and attitudes influence instructional decisions as well as the implementation of innovative practices such as STEAM (Ertmer & Ottenbreit-Leftwich, 2020; Yurnetti, 2021). Educators who hold negative perceptions of the STEAM approach tend to face greater challenges in its implementation and may exhibit resistance or avoidance in applying it in the classroom (Herro & Quigley, 2017; Utami et al., 2021). Responses to the first question in this aspect show that all lecturers from various disciplines have heard about the Industrial Revolution 5.0. This revolution has led to the emergence of the STEAM approach as one of the educational innovations, particularly in enhancing students' Higher Order Thinking Skills (HOTS). Educators, both teachers and lecturers, are expected to possess technological literacy and broad insights so that they are not left behind in preparing students to become future-ready graduates.

For the second question, the majority of lecturers stated that the Industrial Revolution 5.0 has brought changes to the curriculum and teaching methods, particularly in the PGSD Study Program. Curriculum development must always align with the progress of the times in order to respond to current global demands and challenges (Aryanto et al., 2021; Utami, 2019). In addition, a lecturer from the science education field emphasized that science lecturers are among those most affected by curriculum changes because they are required to apply learning models that foster students' creativity and higher-order thinking skills, such as inquiry-based learning, discovery learning, and project-based learning (Satriawan et al., 2020; Suastra et al., 2018). Although all lecturers know or have at least heard the term "Industrial Revolution 5.0," most have never participated in training related to teaching in the 5.0 era, especially regarding the STEAM approach. These findings indicate a gap between the information received and a deeper conceptual understanding, which ultimately influences lecturers' readiness in designing and implementing adaptive learning strategies. This limitation is exacerbated by the absence of systematic follow-up after training, resulting in suboptimal transfer of teaching practices. In the context of 21st century education and the educational vision of Society 5.0, it is essential for lecturers to understand global issues such as the Industrial Revolution 5.0. This knowledge must be transformative rather than merely informative, prompting lecturers to develop innovative strategies such as STEAM based learning.

Thus, it is necessary to strengthen lecturer professional development through thematic and continuous training that links global changes with practical classroom implementation. The more lecturers engage in training or actively seek information about education in the 5.0 era and STEAM, the more their understanding will grow (Santoso, 2019). An important component of a teacher's Pedagogical Content Knowledge (PCK), which influences teaching success and educational system change, is the teacher's own perception of their teaching practices (Srikoom et al., 2017; Trivena & Hakpantria, 2020). Findings related to the attitude aspect show that PGSD lecturers at UKI Toraja hold very positive views regarding the STEAM approach in the learning process. Most lecturers expressed a high level of interest in STEAM based learning and believe that this approach has great potential to enhance students' creativity, critical thinking, and problem-solving skills competencies that are essential in facing 21st century challenges. This perspective reflects a solid understanding of the urgent need for educational transformation in response to the dynamics of the Industrial Revolution 5.0 and Society 5.0. STEAM is no longer a new concept for educational researchers, teachers, or lecturers. In addition, many lecturers believe that the STEAM approach is highly relevant to efforts to align educational development with the demands of the Industrial Revolution 4.0. This aligns with Ghufron's view that the opportunities and challenges of Industry 4.0 have a positive influence on education, particularly in fostering innovation and creativity (Ghufron, 2018). Most PGSD lecturers stated that STEAM related courses are highly useful for enhancing students' creativity and problem-solving abilities two key competencies for success in the 21st century.

Responses from lecturers during the interviews indicate that STEAM is perceived as capable of equipping students with various essential skills (Harahap et al., 2021; Rahmawati et al., 2019). This is consistent with lecturers' opinions in the fourth question, where they emphasized that critical thinking, creativity, and problem-solving abilities are crucial competencies for facing the future. For the third question, all lecturers agreed that the lecturer's role is vital in fostering students' interest in STEAM based learning. However, several also emphasized that this responsibility should be shared among all stakeholders, including university leaders, curriculum designers, facility providers, and the students

themselves. A previous study found that components such as students, lecturers, curriculum, and infrastructure are in the process of alignment to support the implementation of STEAM in universities (Trivena & Langi, 2021). This study also revealed that, according to lecturers, some students do not enjoy STEAM related courses such as Mathematics and Science because they do not clearly understand the learning objectives.

Furthermore, lecturers who teach Mathematics and Science observed that students often struggle to understand the material (Aini et al., 2024). This lack of understanding is partly due to unclear learning objectives, which affects their motivation. Subjects such as Science and Mathematics require high levels of interest and motivation to increase students' willingness and effort to learn (Gafoor & Kurukkan, 2017; Ng et al., 2016; Trivena et al., 2017). All lecturers agreed that STEAM related courses should be prioritized in the PGSD study program. However, several challenges were identified by lecturers and the study program management, including a lack of competent lecturers in related fields, limited tools and facilities, insufficient time allocation, and budget constraints. Currently, there are only five lecturers with backgrounds in Mathematics and Science teaching in the program, and no lecturers from engineering, arts, or technology fields. This aligns with previous findings that positive perceptions of STEAM are not always accompanied by adequate pedagogical and technological competence (Bendriyanti et al., 2022). Implementing STEAM requires lecturers and students to be active participants in the learning process (Trivena, 2018). Although lecturers show strong support for STEAM, strategic interventions are still needed, such as ongoing professional development, integrative curriculum design, the provision of learning facilities, and systematic orientation regarding STEAM for students. These efforts are crucial to ensuring that the lecturers' positive attitudes translate into actual learning practices and eventually improve the quality of science education in elementary schools.

Facilities are one of the important supporting components that enable educators to provide optimal learning experiences for students (Zalli et al., 2020). Based on the findings, facilities supporting STEAM-based learning in the PGSD Study Program at UKI Toraja are still considered limited. Lecturers stated that although courses such as Mathematics, Science, and Computer Studies are included in the curriculum, there are no specific activities or dedicated training classes designed to support STEAM learning, such as additional courses, workshops, or integrated programs. This indicates that support for interdisciplinary learning has not been optimally accommodated in academic or non-academic programs (Putri & Wibowo, 2021). The lack of student participation in competitive activities such as mathematics and science Olympiads also reflects limited facilities and motivational support for developing science and technology skills. Furthermore, field trips or science exhibitions have not become routine or structured programs to enhance students' scientific literacy, even though these activities should serve as contextual learning opportunities. Lecturers' perceptions of educational infrastructure significantly influence learning effectiveness, particularly in the use of laboratories and science/mathematics teaching kits (Rabbani & Aliyyah, 2024).

Although science and math kits and physics and computer laboratories are available, these facilities are not specifically designed to support STEAM learning that integrates Science, Technology, Engineering, Arts, and Mathematics holistically. This condition indicates a gap between the available facilities and the demands of innovative, interdisciplinary, and project-based learning approaches. This study aligns with previous findings that the success of STEAM implementation is influenced by the availability of instructional media and a curriculum responsive to the needs of 21st-century learning (Syahrul, 2023). The limited supporting facilities present a major challenge in implementing STEAM in the PGSD study program; therefore, integrated and sustainable facility development through the establishment of a STEAM laboratory, project based training, science field trips, and external collaborations with educational institutions or industry is needed to overcome these challenges (Rahmi et al., 2020; Sukmawati et al., 2023). These efforts are essential to ensure that STEAM is not merely a conceptual framework within the curriculum but is genuinely reflected in students' real learning experiences. This includes implementing learning models that require the support of media and learning tools. STEAM based learning fundamentally requires adequate infrastructure and resources in order to be effectively implemented in the classroom (Li & Schoenfeld, 2019; Rahmi et al., 2020).

The practical implications of this study include the need to design thematic and continuous training programs for lecturers, provide integrated STEAM based laboratory facilities, and develop structured plans for academic activities such as scientific visits or science exhibitions. Theoretical implications indicate that implementing STEAM in elementary teacher education requires synergy between individual readiness (lecturers) and systemic support from the institution. However, this study has several limitations. The small number of informants (six lecturers) limits the generalizability of the findings. In addition, this study focuses solely on lecturers' perceptions, without incorporating data on actual STEAM implementation in the classroom or its impact on student learning outcomes. Therefore, future research is recommended to

expand the scope of investigation, both geographically and in terms of participant numbers. A mixed methods approach can be used to examine the relationship among perceptions, facilities, and STEAM implementation from both quantitative and qualitative perspectives. Additionally, evaluating the effectiveness of STEAM training programs for lecturers and conducting longitudinal studies on the integration of STEAM into elementary teacher education curricula would be highly valuable directions for future research.

4. CONCLUSION

Based on the research findings, it can be concluded that PGSD lecturers hold a generally positive perception of STEAM based learning in terms of knowledge, attitudes, and responses to supporting facilities. Lecturers demonstrated a sufficient understanding of the Industrial Revolution 5.0 and the STEAM approach, as well as its relevance to curriculum development within the PGSD program. In terms of attitude, lecturers expressed a favorable view of the importance of implementing STEAM to foster 21st-century skills such as critical thinking, creativity, and problem-solving. However, the existing learning facilities within the program are not yet fully supportive of optimal STEAM implementation, particularly in terms of its integration into the teaching and learning process. This suggests that although lecturers are conceptually ready, institutional support needs to be strengthened to ensure that STEAM based learning can be effectively and sustainably implemented.

5. ACKNOWLEDGEMENT

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