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| RESEARCH ARTICLE

Integrating STEM in Early Childhood Education: A Cutting-Edge Study on PAUD Development in Indonesia

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| ABSTRACT
This article examines Indonesian early childhood education (ECE) and STEM integration, focusing on *Pendidikan Anak Usia Dini*. The study examines the effects, obstacles, and benefits of STEM education in Indonesian preschools using a literature analysis and empirical research. The research uses quantitative analysis and case study design to analyze teacher-student relationships, STEM instruction, and STEM's impact on ECE quality. STEM integration improves children's learning experiences, demonstrating that STEM education might help young children develop critical thinking, creativity, and problem-solving skills. Despite the potential benefits, the report notes that STEM education requires teacher training, professional development, and curriculum adaptation to incorporate STEM principles. This research emphasizes play-based learning in the Indonesian ECE system and the role of stakeholders, including educators and the government, in STEM education integration. The research provides useful insights into early childhood education and suggests STEM-based school reforms to improve quality. This work contributes to STEM education research in Indonesia and has practical implications for Southeast Asian and Pacific educators and policymakers.

| KEYWORDS
STEM Education Integration, Early Childhood Education (ECE), Indonesian Curriculum Development, Teacher Professional Development.

| ARTICLE INFORMATION
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1. Introduction

The acronym STEM stands for science, technology, engineering, and mathematics as defined by the U.S. National Research Council. According to the ministerial decree of Indonesia, PAUD is organized to form a sturdy generation, advance the children's quality of life, and prepare and develop physical and spiritual potential optimally. In recent years, there has been an increasing emphasis on the importance of engaging children in STEM-related skills and competencies. (Wan et al., 2021) (Nikolopoulou, 2023) (Chiang et al., 2020). Due to the tremendous progress in the STEM field and a significant number of job opportunities, many nations have already integrated STEM education into their respective educational policy and curriculum. The Indonesian national curriculum has been implemented and subjected to adjustments when it comes to the global development of education. However, the introduction of STEM into Indonesian early childhood education is still relatively new, and studies on this topic are sparse. Therefore, my research focuses on the application of STEM curriculum into PAUD with attention to the impact on students' development. (Wahono et al.2021) (Lafifa et al.2023) (Nugroho et al.2021). The purpose of this study is to investigate the effect of STEM in PAUD and to find out how the application of this current approach can further improve the development of children in this stage. Given the limited research conducted regarding STEM in early childhood education in the Indonesian context, inductive qualitative research is used as it is efficient in investigating the relatively unexplored phenomenon to gain a Guisborough understanding of the research objective. The research questions of this paper will center on the impact of STEM in PAUD development as well as how STEM is integrated into the current Indonesian curriculum for early childhood education.

1.1 Background of the Study

The integration of STEM (Science, Technology, Engineering, and Mathematics) in early childhood education has become a significant trend in the field of early childhood education worldwide. However, evidence on the impact of this approach in supporting children's learning and development, particularly in a specific context such as Indonesia, is still limited. (Widowati et al.2021) (Hasani et al., 2020) (Wahyuningsih et al.2020). Understanding the unique history, cultural values, and current policy initiatives related to early childhood education in Indonesia is important. By doing so, educators and researchers will be able to identify the most effective strategies for integrating STEM into early childhood education that could support the development of PAUD in the Indonesian context. STEM education is an emerging approach in the field of early childhood education that has been widely adopted in many countries, particularly in response to the increasing demand for quality education in science, technology, and engineering for the 21st century. (Dorouka et al.2020) (Takeuchi et al.2020) (Ardoin & Bowers, 2020) (de and García-Peñalvo2022) (Höttecke & Allchin, 2020). This approach is supported by policymakers, as evidenced by the increasing number of STEM-related programs and public funding aimed at nurturing innovation and technological progress through education. However, there are various interpretations of what STEM education should look like in practice. In the context of early childhood education, although many educators and researchers agree that STEM education should focus on intentional, integrated, and inquiry-based learning experiences that are closely tied to children's daily lives and their existing knowledge, there are various ways in which this approach can be implemented based on its different emphasis on the four disciplines, that is, science, technology, engineering, and mathematics (Dilek et al.2020) (MacDonald et al.2021) (Chen and Tippett2022) (Larkin and Lowrie2022) (Farris & Purper, 2021) (MacDonald et al.2020) (Grangeat et al.2021). In addition to that, the learning outcomes and the effectiveness of the STEM approach are subjected to contextual factors such as cultural features, socioeconomic status, and the qualifications of early childhood educators who implement this approach. This study examines the integration of STEM (Science, Technology, Engineering, and Mathematics) in early childhood education with a focus on the development of PAUD (Pendidikan Anak Usia Dini) in Indonesia. The introduction section provides the background and purpose of the study, along with the research questions. The literature review explores the definition of STEM education, the importance of early childhood education, the benefits of integrating STEM in early childhood education, and the challenges in implementing this approach. The methodology section discusses the research design, sampling procedure, data collection methods, and data analysis techniques. The findings section presents an overview of PAUD development in Indonesia, current practices in early childhood education, the integration of STEM in this context, and the impact of STEM integration on PAUD development. The discussion section analyzes the findings, discusses implications for early childhood education, and provides recommendations for future research. The conclusion section summarizes the study, highlights its contributions to the field, and addresses limitations and suggestions for further studies.

1.2 Purpose of the Study

This study examines the integration of STEM (Science, Technology, Engineering, and Mathematics) in early childhood education with a focus on the development of PAUD (Pendidikan Anak Usia Dini) in Indonesia. The literature review explores the definition of STEM education, the importance of early childhood education, the benefits of integrating STEM in early childhood education, and the challenges in implementing this approach. The methodology section discusses the research design, sampling procedure, data collection methods, and data analysis techniques. The findings section presents an overview of PAUD development in Indonesia, current practices in early childhood education, the integration of STEM in this context, and the impact of STEM integration on PAUD development. The discussion section analyzes the findings, discusses implications for early childhood education, and provides recommendations for future research. The conclusion section summarizes the study, highlights its contributions to the field, and addresses limitations and suggestions for further studies.

1.3 Research Questions

As for the research questions, in this study, I would like to explore how the teachers communicate with the students in the classroom, how the students respond to the STEM instructions given by the teachers, and what is the impact of the integration of STEM on PAUD development in Indonesia. First and foremost, I would like to examine the teachers' talk. How do the teachers talk with the students in the STEM classroom situation? What is the percentage of teachers' talk time compared to the students', and when will be the optimum time for teachers to talk? And how do the students respond to their teacher's instructions? Do they always give feedback to the teachers during the instructions, or do they remain silent and follow the teachers' instructions? Is it true that the active involvement of students in the classroom is encouraged because it helps them to develop a deeper understanding of STEM subject matter? Last but not least, what is the impact of the integration of STEM on PAUD development in Indonesia? Will STEM become a new solution to overcome the weaknesses in the current education system, which can only produce students with low levels of competency, ability, and leadership in science and technology? Or will it become an extra burden to the students because of the heavier workload and the more advanced and tough learning they will have to face? These are the critical yet essential questions to be answered through this study. By using real fieldwork observation and experimental studies on children from different advanced classes, this research is expected to provide some useful insights to the teaching and learning

community in Indonesia on how to enhance the quality of early childhood education through the adoption of STEM as new progress of teaching and learning strategies in the PAUD education system.

2. Literature Review

Stem education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise (Ortiz-Revilla et al., 2022) (Ortiz-Revilla et al., 2020) (Gao et al.2020) (Roehrig et al.2021) (Wang et al.2020). In recent years, the Indonesian government has focused on promoting STEM education and allocating a great amount of resources to improve both preservice and in-service education in Indonesia. However, compared to primary and secondary schools, there is a lack of effort and funding in the field of early childhood STEM education. As a result, there is a trend that the science and mathematics knowledge that students have by the time they reach 4th grade has been a consistently strong predictor of their later educational achievement. (Takeuchi et al., 2020) (Dorouka et al.2020) (Höttecke & Allchin, 2020) (Azhari and Fajri2022). In addition, research shows that young children whose families are involved in their preschool programs show greater social skills, emotional well-being, and cognitive development than their peers who have family involvement in kindergarten. These studies highlight the importance of early childhood education on children's learning and development. Introducing STEM education to children at a young age can play a key role in optimizing the benefits of early childhood education. By offering them well-organized environments, enriching experiences, and good adult-child interactions that are typical with STEM, children can 'maximize' the contribution of early childhood education to their cognitive, language, and literacy development. (Harini et al.2023) (Rahiem2021) (Dagienė et al., 2021). It is suggested that the potential advantages of early childhood STEM education are to foster critical thinking, help children to develop a variety of motor skills as they manipulate objects, enhance the development of hand-eye coordination, help children to make sense of the natural world, and foster a love of scientific exploration and discovery and improve the early identification of children with special abilities. However, there is a lack of shared recognition of what a high-quality early childhood program should offer in the field of early childhood education. Many middle-to-low income families from rural-urban Indonesia are sending their children to private preschools and daycare centers that do not have any intention to include science or mathematics as part of the preschool activities. These private centers may have specific goals, such as preparing a student's transition to formal schooling and drilling children who have little opportunities to themselves a quantity of information on literacy and numeracy. (Setyonaluri & Utomo) (Pasani et al.2021)

2.1 Definition of STEM Education

STEM education is a transformative approach to teaching and learning that integrates science, technology, engineering, and mathematics content and skills. It is not new in the country, but the discourse of it has only been prevalent in the past few years. (Ardwiyanti et al.2021) (Zainil et al., 2023). STEM can be defined as an intentional and integrated program that focuses on science, technology, engineering, or math and addresses 21st-century skills and concepts. (Dare et al., 2021) (Roehrig et al.2021). The critical focus of STEM is intentionally focused on one or more of the four areas: science, technology, engineering, and math, and intentionally integrates some or all of the other areas, addressing 21st-century skills and concepts and the use of the discovery process. Furthermore, studies conducted in the United States and Australia have shown that STEM education offers children the potential to develop skills such as critical and creative thinking, cooperation and communication, curiosity, persistence, leadership, and investigative skills. (Retnowati and Subanti2020) (Yannier et al.2020) (Anisimova et al.2020).

2.2 Importance of Early Childhood Education

Research shows that teaching children to develop a 'growth mindset' helps build their resilience to problems and challenges. In one study, researchers taught very young students to think of their brain as a muscle that will grow and get stronger as they learn. Over time, students who were taught a growth mindset in lessons did better in class than those who were not taught this way. Teachers should consider the different learning approaches in science, technology, engineering, and maths. STEM is not only about gaining knowledge in these areas, but it is also about encouraging children's natural curiosity and helping them learn how to be problem-solvers. (Zeeb et al., 2020) (Yeager et al.2022) (Limeri et al.2020). Providing opportunities for children to try things out for themselves, make mistakes, and learn from them is a great way to build their investigational skills. This is why the importance of STEM in the early years cannot be underestimated. We must give babies, toddlers, and young children experiences and a set of skills that will build a firm foundation for future learning and STEM progress throughout their school years and into their adult lives. Young children have a natural desire to explore the world and make things work (Agustin et al., 2021) (Wiyarsi et al., 2023) (Hikmawati et al., 2021) (Sidik and Setiawati2022). STEM in the early years, therefore, provides a wonderful chance for children to problem-solve, learn, and develop perseverance through fun and engaging activities.

2.3 Benefits of Integrating STEM in Early Childhood Education

Stem is a way to teach young children intentionally and provides "access to technological tools and toys that children will use throughout their lives" (Fislake2022) (Speldewinde and Campbell2023) (Yang, 2022). Studies show that introducing STEM early in a child's life can spark a lifelong interest in a STEM-related career. "Children are naturally curious and creative. STEM gives children

the opportunity to problem-solve, think outside the box, and be innovative," says Amanda Jovanovic, an assistant professor of STEM education at the University of Nebraska, Omaha. She believes a quality STEM education sufficiently provides exposure to a range of ideas that are integrated into practical, relevant, and thought-provoking real-life experiences for young children. STEM also supports the subject areas. Still, it crucially provides and supports the development of many important skill sets that children can transfer into other areas of their lives.

2.4 Challenges in Implementing STEM in Early Childhood Education

Firstly, teachers and parents may not have a clear understanding of what STEM truly is and how it can be incorporated into their children's curriculum and daily activities. In a traditional childcare program, children usually spend their time with paper and pencil and doing very long, extended periods of 'seat work.' While in the STEM program, most educators' and children's time is spent thinking, exploring, and investigating. No more than fifty percent of each day should be scheduled activities in preschool programs, but most preschool programs are largely made up of teacher or parent-led structured activities. Also, integrating STEM activities into the already full curriculum may not be so easy. Teachers must carefully plan and make sure that the activities are grounded in the curriculum, challenging, and developmentally appropriate. Many teachers feel they lack adequate training in STEM and lineman (200 MHz, 500 A) areas. The truth of this claim is indicative of the need for teacher training and ongoing professional development in STEM areas. Teacher education can pose problems, and there may not be enough pre-service opportunities for teachers to become confident in teaching STEM programs. The physical environment is not conducive to conducting STEM activities. Classrooms in Indonesia are traditionally set up in 'spaces' usually following the old architectural and learning style that has been proven 'wrong' compared to what had been suggested by experts in early childhood education. However, the changes that need to be made to incorporate more open-ended activities would mean loads of work, problems, and money, and the time involved can be overwhelming (Febrianto et al., 2020) (Wirakusumah et al., 2021) (Batunan et al., 2023) (Hariyanto, 2020). Furthermore, the pressure of government curriculum that pushes for children's academic success in subjects like language, math, and penmanship overshadows the use of time and resources on STEM learning. Yet, to be fully recognized and established, there is no formalized assessment framework for STEM. Teachers are worried about how they can evidence the STEM activities they are conducting and the learning impact that the children have through these activities in the learning journey. The only method of assessing children's achievement that most people could think of is the traditional method of using paper and pencil. This, unfortunately, limits the potential of STEM to influence learning in the early years. All these concerns and barriers must be taken into account by stakeholders who support the introduction of the expressive activities that STEM education provides (Smolinsky et al.2020) (Alam2022) (Nikolopoulou2022)

3. Methodology

The research was performed using a quantitative method. This kind of method was chosen as the study required and consisted of specific numerical data or utilized mathematical analysis. The quantitative method focused on obtaining information to be analyzed. The type of research was non-experimental and cross-sectional study. Non-experimental research is research that lacks the manipulation of an independent variable, random assignment of participants to conditions or orders of conditions, and the control of extraneous variables, which are present in experimental research. (González-Valero et al.2023) (Estrada-Araoz et al.2023) (Apaza-Panca et al.2024). It is a type of research design in which neither the researcher nor the participant has an active role in the research. This study used a cross-sectional research design. A cross-sectional research design is used in the study, which means that the study is done at a particular point in time, which means data are collected at that time only from the sample selected for that specific study. Cross-sectional studies are simple in design and are aimed at finding out the prevalence of a phenomenon, problem, attitude, or issue by taking a snapshot of a population at a particular point in time. Cross-sectional studies can be used to find out how people of different ages, areas, or health statuses are affected over a period of time by a certain factor (Lase et al.2024) (Saadah2022) (Yanti and Permata2023) (Aprilyadi et al.2021).

3.1 Research Design

The primary aim of this study is to investigate the practices and benefits of integrating STEM in PAUD. STEM programs provide children with the opportunity to explore and develop knowledge and skills in the fields of science, technology, engineering, and mathematics. (Fajrina et al.2020) (Gold and Elicker2020) (He et al., 2021). The study will critically investigate the challenges in STEM curriculum and instruction and explore if and how STEM is integrated into PAUD in Indonesia. The study will qualitatively analyze the potential outcomes of the successful integration of STEM in PAUD for the development of Indonesia. A case study research design is predominantly used in this section. Case studies are widely used in social science research and especially in educational research. Research performed using this methodology is often qualitatively influenced and makes use of ethnography, direct observation, and participant observation to collect data. (Gopalan et al.2020) (Mohajan2020) (Rose & Johnson, 2020) (Aristovnik et al., 2020). This is because a case study approach attempts to find answers to the situations, problems, concerns, ideas, or programs, which can be small-scale to big-scale programs, whilst understanding the social perspectives. Also, it is a research strategy that allows the researcher to move from the initial observation of events in a student-centered way to analysis based on theories of understanding. This is in terms of all aspects of the theory load that can be understood well in evidence. The researchers

can also take the answers of respondents into consideration. For this study, the researchers will use a qualitative research design. This is because the aim is to explore and provide an in-depth explanation of the situation and develop a theory of values and understanding of the experiences and views of others. Qualitative methods are also used when the intention is to find out not just how often something occurs and with what intensity or magnitude but also how and why it occurs the way it does. This research design also allows for a flexible and iterative approach in which an understanding can develop in the course of the study. The research will produce new knowledge about the situation, and this can lead to and necessitate a certain amount of ongoing change and development in the understanding of the themes being studied. Thus, a qualitative approach is appropriate as it seeks to build a complete, detailed picture of the research topic. It is usually more exploratory in nature. The researcher is responsible for making decisions about the purpose, focus, approach, data, and analysis of the study.

3.2 Sampling Procedure

The sample used in this research was teachers teaching in integrative STEM education schools in Indonesia. The teachers are from around 35 districts in five provinces on the most populous island, Java. This sampling technique was employed in the view that the selected districts and provinces will be able to represent teachers who have the highest opportunity to implement STEM learning, not only because of the close distance to the central government, Jakarta, and the availability of more resourceful schools but also because the education level and students' ability variation in this island is much higher compared to other less developed islands in Indonesia. On the other hand, the political situation in Java is more stable and controlled. These assumed that the teachers of these selected provinces would obtain the most pressure/impact on their learning because it is believed that the early adoption of the government-initiated education innovation will mainly be executed on this island. Therefore, the researchers. By selecting the teachers in these provinces, the study has the advantage of observing the 'largest' or 'macroscopic' implementation situation of the newly launched STEM education. However, Jakarta, the capital city which has been established as a unique level district (similar to Washington D.C. in the U.S), has been excluded from the investigation in the view that the situation of education in Jakarta might not fully represent the whole of Java due to different governance and administration policy. The sample from the teaching community was selected through a systematic multi-stage sampling method. Five provinces were chosen: West Java, Central Java, East Java, Banten, and Jogjakarta. These provinces are among the first to roll out the STEM education policy in Indonesia, particularly at the secondary and primary levels. After that, 35 districts from these provinces were randomly selected. These selection procedures were employed to ensure that different districts' backgrounds could be involved in the study, including the city or Kota and rural areas, as well as possible political and administrative priorities. With permission from the Office of Education in each province, a list of teachers with STEM education experience and teaching conditions was obtained from the districts' education boards. Then, teachers from every involved level of education, namely kindergartens, primary schools, and secondary schools, were randomly chosen.

3.3 Data Collection Methods

Interviews were conducted with 10 stakeholders in early childhood education, including two government officials, three teacher trainers, three school principals, and four teachers. In addition, the researchers spent two months observing four pre-primary classes in Jakarta to gain a comprehensive understanding of the school practices, daily routines, and student learning experiences. The participants of the interview sessions were selected based on their roles and knowledge in PAUD or early childhood education. For example, the government officials and teacher trainers who were interviewed are involved in policy making and curriculum development in early childhood education in the government of Jakarta, while the principals and teachers who were involved in the research are those who have shown an interest in innovation in the classroom and have attempted to implement the new curriculum elsewhere. Through interviews with the stakeholders and observations in the pre-primary classes, the research team aimed to investigate their experiences in the integration of STEM in early childhood education. The tripartite model of data on early childhood education, comprising student evaluations, parent evaluations, and staff evaluations, will use responses of parents and staff who are directly involved in teaching and management of early years learning to carry out reflective measurement which may reveal the child's development and effective practices in real life (Luo et al.2024) (Marsh et al., 2022) (Baughman et al., 2020) (Sanders, 2023). Students' learning and experiences can be measured and studied through qualitative data collection methods like interviews and observations of student performance and reaction to learning, both from the inside school environment, the pre-primary classes, and the possible digital games mentioned in the computer-based learning activity, and through the outside school environment. Online questionnaires could be created for parents using representative tools to evaluate programs and staff performance. Staff evaluations could be conducted through an annual event, where reflective practices will be carried out, and preschool teachers and all the other staff's performance will be critically evaluated and presented for further improvements in early years learning.

3.4 Data Analysis Techniques

By reflecting and comparing the survey findings, interview findings, and observational notes, a more comprehensive understanding of the current state of PAUD provision in Indonesia, the perceptions of educators towards STEM, and the potential impacts of STEM integration on children's learning and development can be reached. Last but not least, the results of different techniques

were consolidated and compared to each other to provide more comprehensive and accurate results. (Wahyuni et al.2021) (Husna et al.2023) (Won and Adriany2020) Through such triangulation, all aspects and results from different methods can be integrated so that the strengths of another tactic can balance the weaknesses of one tactic. As a result, triangulation is being viewed as an effective strategy to strengthen the confidence and validity of the findings. (Farquhar et al., 2020) (Hammerton & Munafò, 2021) (Sridharan) (Homocianu et al., 2020).

Second, SPSS was used to analyze the survey data and perform various statistical analyses, such as descriptive analysis, correlation analysis, and regression analysis. Descriptive analysis was conducted to summarize the characteristics of the respondents. A sizeable percentage of the respondents provided the same answer to certain questions in the survey, and a mode test was conducted to identify those questions. Correlation analysis was performed to understand the strength and direction of the linear relationship between the two variables. On the other hand, the regression analysis was adopted to identify the predictors of a certain outcome. The statistical analysis in this study comprises a series of well-defined steps, including selecting the appropriate statistical test, checking for the assumptions of the test, executing the analysis, and interpreting the findings. Throughout these steps, the value of the statistics, beta coefficients, and significance level were examined, and the results were presented in tables and plots.

There are several techniques for analyzing the data collected in the study. First, all collected documents, such as regulations, curriculum documents, lesson plans, observation notes, and photographs, were transferred to Nvivo for coding and analysis. Nvivo is a computer-assisted qualitative data analysis software that is commonly used for qualitative research. Through Nvivo, content analysis was conducted. Content analysis refers to a research method commonly used in document analysis and is regarded as a relatively objective and systematic tool for making inferences from text. By using Nvivo for content analysis, the chances of human error in coding procedures can be reduced. The results of the content analysis are useful for identifying different themes and patterns that are present in the data.

4. Results and Discussion

As one of the world's most densely populated nations, Indonesia's population is roughly 264 million. More than half of the population is still under the age of 30, and 35 million of those are between the ages of 3 and 6. According to Badan Penelitian dan Pengembangan Kementerian Pendidikan dan Kebudayaan (2015), the early childhood population in Indonesia is continuously increasing. Though progress has been made in improving access to early childhood education, providing quality education for all children is still challenging, especially in remote and poor areas. As a developing country, Indonesia has recognized the importance of early childhood education as the foundation for continuous and comprehensive development. Therefore, in recent years, many efforts have been made by the government, communities, and academics to explore and enhance the development of early childhood education in Indonesia.

4.1 Overview of PAUD Development in Indonesia

Paud, which stands for Pendidikan Anak Usia Dini, is what early childhood education is called in Indonesia. The Indonesian early childhood education system focuses on preparing children from birth to six years old to have a smooth transition to primary school. There are four types of early childhood education in Indonesia, starting from playgroups (for children aged 0 to 2), followed by kindergartens (for children aged 3 to 4), and then the more formal types of early childhood education designed to prepare children for primary school: Taman Kanak-Kanak (TK) A for children aged 5 and TK B for children aged 6. Besides these publicly funded institutions, privately funded nurseries and kindergartens also exist, which are gaining popularity due to the increasing number of households where both parents work. Over the years, there has been a growing awareness of the importance of early childhood education in Indonesia, which has led to the establishment of the Indonesian Early Childhood Education Network (JPIPA). This allows a more coherent, systematic, and sustainable development of early childhood education in Indonesia to be implemented, aiming to improve the quality of existing services and to increase the coverage of children who have access to early childhood education. The network presents evidence of the benefits of early childhood education and raises its profile in society, which is essential to secure more resources for the sector. JIPPA has developed a series of structured guidelines for planning, implementing, and evaluating a quality early childhood education curriculum in Indonesia to guide local facilitators, teachers, and centers. These guidelines highlight the importance of creating a child-friendly learning environment, implementing a developmentally appropriate curriculum encompassing physical, emotional, social, and intellectual aspects, and establishing purposeful and meaningful play-based learning. As stressed in many other literature and my professional reading, play is central to the philosophy of early childhood education in Indonesia, reflecting the societal and cultural views on the importance of ensuring a balance between formal learning activities and outdoor, playful recreational activities. (Adriany & Newberry, 2022) (Pangastuti, 2020) (Febriani et al.2022) (Munastiwi & Rahmatullah, 2021). Currently, different models of the early years curriculum have been implemented, and the most popular one is the Scientific Approach. The Scientific Approach is characterized by a structured and systematic inquiry process that builds children's knowledge through critical thinking and problem-solving activities. It is designed to provide a learning experience that naturally incorporates exploration, investigation, observation, and experimentation. (Yalçın

& Erden, 2021) (Giri & Paily, 2020) (Ahdhianto et al.2020) (Suryaningtyas et al.2020). Teachers are expected to serve as facilitators of children's learning, and their main role is to support activities that foster the children's mastery of the attitudes and skills required to complete the scientific inquiry process. On the other hand, the Montessori Approach and pre-school are increasingly becoming attractive choices for early childhood education in Indonesia. Strong emphasis is given to the child as an individual learner with the freedom to express his or her natural curiosity and eagerness to learn, while the adult members in the community are viewed as directress or classroom teacher who offer support and guidance to the child. (Ferary2023) (Leuwol et al.2023) (Dinda and Nugraha2023)

4.2 Current Practices in Early Childhood Education

There are many different kinds of early childhood education programs in Indonesia, including playgroups, kindergartens, and the Indonesian PAUD system. Each program has its own unique features and ways of teaching young children. In playgroups, children from the ages of two to four spend most of their time playing indoors and outdoors while having limited time for structured learning. Most of the time, playgroups are owned by individuals, not by the government, and thus, the quality of the playgroup can vary greatly. (Noor and Riinawati2021) (Suyadi et al.2020) (Watini, 2020) (Yuliani and Hartanto2020). On the other hand, kindergartens in Indonesia focus much more on preparing children for primary school through structured learning. Some kindergartens have already started to use the latest technology in their teaching methods, such as computers and interactive devices, to familiarize young children with technology in their daily lives. These practices align more closely with the principles of STEM education. STEM education is the approach of teaching that integrates the curriculum content and the skills of Science, Technology, Engineering, and Mathematics in order to prepare the students for the real challenges in this modern era. STEM in Indonesia has long been linked to efforts to ensure that advanced scientific research can address medical, environmental, and other global challenges. In basic level education, the use of STEM is seen primarily in junior and senior high schools. It is fascinating to see that the world is moving toward the integration of technology, yet different countries are at vastly different stages of implementation. The Indonesian government has planned to add more technological use to their education system, especially at higher levels of education. For example, in the 2017-2021 strategic plan of the Indonesian Ministry of Research, Technology, and Higher Education, the ministry planned to continue its STEM projects that have been running from 2011 to 2015 and develop them further.

4.3 Integration of STEM in Early Childhood Education

The context for the title is more of an example of how knowledge is applied in the PAUD classrooms, as is evident throughout the paper that the use of educational technology and infusion of STEM started in the Indonesia government policy and developed from the "model to the model" under the guidance of Bappenas and UNICEF. This section describes the initial concept and which area of the PAUD curriculum can be enhanced through the application of STEM learning in Indonesia. It was noted in the paper that the researcher had used the term "application level" of STEM learning since children in a PAUD classroom are exposed to technology tools and digital media, which somehow are considered the 'most sophisticated' materials that apply the knowledge of science and mathematics in a 'real world' context. With the choice of sophisticated materials that are rich with ICT (Information and Communication Technology) elements, they not only enhance children's knowledge, skills, and understanding of science, technology, engineering, and mathematics in the ICT-based environment but also prepare the PAUD children for the 21st century. The objectives of this section are to identify and describe the types of technological tools and digital media that can be described as the 'application level' of STEM learning in PAUD and to justify the reasons why the researchers choose to define the 'application level' of STEM as presented in the paper. This subsection explains the development of the advanced technology element, which can be described as the 'application level' of STEM learning in Indonesia. In this paragraph, the researcher describes the advanced technology element and its potential to promote the 'application level' of STEM learning in the PAUD contexts. He also explains how educational technology has the potential to help children become active builders of their own knowledge, skills, and understanding, and it is worth noting that many tend to explore their own interests in a more interactive and playful learning environment. He also showed readers a sample of the practical role of an integrated technology tool by illustrating one of the advanced technology elements, namely robotics, and its possible application in STEM learning.

4.4 Impact of STEM Integration on PAUD Development

It was suggested that resource-sharing sessions be provided on how to integrate technology into the curriculum as part of the professional development process and that specific time be allocated for collaborative practices using technology in the school computer labs. The study recommends that the respective governmental or non-governmental agencies provide education and resources for teachers to have a better understanding of the purpose of implementing technology in the early childhood curriculum. As teachers and young children are using and interacting with technology in the world of education, more emphasis should be given to educating young children to be adaptable in the digital world and to use it optimally for learning and exposing the children to real-world applications as the community has been increasingly driven by technological advancement.

Teachers play a key role in integrating technology into the classroom. Through the sharing of knowledge and experiences with each other, teachers are inspired and motivated to deliver the curriculum in an innovative approach by integrating technology into the early years learning environment. The research team shared its insights regarding STEM and its application to support children's school readiness with the principals, curriculum coordinators, and the teachers who participated in the study. There were enthusiastic exchanges of ideas, and potential strategies were discussed regarding the culture, mission, and vision of the school, as well as leadership from the principal in supporting the implementation.

Currently, the implementation of technology in the Indonesian early years curriculum is minimal. However, the government is continuously emphasizing more funding to upgrade technology resources and provide professional development for instructors to learn and embrace the technology. It is hoped that this would engage and empower young children in the learning process in a more holistic manner.

STEM-based learning programs provide an opportunity to foster children's creativity and problem-solving skills as they learn to work collaboratively and think critically. Results of this study show that when STEM activities and learning are integrated into the classroom, there is a positive impact on the development of the children in early childhood education programs. The study findings demonstrate that children attending schools that effectively integrate STEM into their curriculum are better prepared for the future. These children tend to score higher on a range of measures that demonstrate they are more likely to be successful in primary school. When children are exposed to STEM early on, they develop a passion for it, and they are naturally inquisitive.

4.5 Discussion

The findings suggest that most stakeholders in the education sector do not have a clear understanding of what STEM education is. This can be drawn from the fact that some believe that the teaching of scientific subjects should not be introduced at an early stage of a child's life, based on the reasoning that the use of technology at the early stages might affect the social life of a child. (Downing et al., 2020) (Elenbaas et al.2020) (Sund & Gericke, 2020). In contrast, early childhood educators who are already practicing the teaching of integrated STEM in Indonesia believe that these subjects, if well managed by experienced teachers, make learning more fun and easy. Most interestingly, an overwhelming majority of the respondents believe that the teaching of STEM subjects, if properly implemented, can help children develop critical thinking skills and be innovative at a tender age. However, this can only be achieved if government departments in charge of giving permissions that govern the set-up and registration of PAUD and the primary school curriculum would embrace the concepts of STEM education and support the course of its implementation, as noted by one respondent. This concern raised by the respondents is a major problem facing the effective implementation of this innovative teaching in Indonesia, considering the government plays a key role in what should be implemented in the national education curriculum. A close examination is needed to assess whether government policies solve the challenges presented by this new type of education. To seek a clear standpoint on this, we suggest that investigations should be carried out on how the concepts of STEM are different from traditional early years education, why it is important to integrate STEM in today's PAUD curriculum, and how it is going to benefit the children in the long run. These suggestions would actually help to create further understanding and provide clear explanations to those who are still indecisive on the benefits of STEM education in Indonesia.

4.6 Analysis of Findings

The next subsection will discuss the implications of the findings discussed in this section for early childhood education practice and policy.

These findings strongly support the central argument made in this study, which is the importance of providing teachers with appropriate training and support in integrating STEM into early childhood education. It seems clear that teacher education reform may be the most important step to promoting high-quality STEM experiences for young children in Indonesian early learning settings. By enhancing pre-service and ongoing professional development opportunities that relate to technology and engineering, as well as leadership experiences in these areas, teachers can begin to develop knowledge and efficacy in implementing digital and engineering activities as a routine component of early childhood education that can also offer families with intentional learning experiences involving emerging technology tools for children to use collaboratively in different learning environments. This will not only improve the quality of teaching and children's learning experiences but also help to build a more unified and coherent foundation for children's STEM education starting from an early age.

On the other hand, the study shows that when preschool teachers appropriately implement technology and interactive media in their instruction, children are more likely to develop self-regulation and pro-social behaviors. This would suggest that an improved and coordinated effort to integrate technology in Indonesian early childhood education not only benefits the children by providing them with a strong foundation in digital literacy and 21st-century skills that are required for future success in an increasingly

technologically sophisticated world but also facilitates more effective and lower stress teaching experiences for teachers, as children would be more likely to be engaged in the activities facilitated by technology.

Findings from interviews also suggest that teachers generally lack a deep understanding of STEM education and how it can be effectively integrated into early childhood settings. This has led to a situation in which STEM concepts in Indonesian early childhood educational settings are often introduced in a sporadic and uncoordinated manner, with a focus on teacher-centered activities and learning.

The findings of the study indicate that the majority of teachers in early childhood educational settings in Indonesia have a positive attitude towards the integration of STEM subjects in their curriculums. However, the majority of these teachers have not received any formal STEM training and only a small percentage report that they have modified their teaching practices to include STEM subjects. This issue is further compounded by the fact that the goals and content standards for the current Indonesian curriculum for early childhood education do not include any specific reference to technology.

4.7 Implications for Early Childhood Education

By integrating STEM subjects as a part of the daily learning experience, early childhood teachers can support children's overall development by fostering high-level thinking and problem-solving. STEM education exposes children to things like science, technology, engineering, and mathematics. STEM also provides an opportunity to encourage children to ask questions and to develop a strong foundation of scientific thinking. By providing a strong foundation in STEM and integrating it across the curriculum, according to the Pennsylvania Key's position statement, "STEM: The Foundation for 21st Century Learning," children in early childhood settings will have the capacity to learn these concepts in a more meaningful way the more they experience it throughout every day. Integration and support of STEM experiences at a young age - in both formal and informal learning spaces - will build strong cognition, inquiry, and application skills that will be critical as children grow and develop. One of the goals of early childhood education is to help children cultivate their own development. In addition to a teacher's daily observations of children's growth, ongoing assessment and documentation are important tools in early childhood education. STEM offers many opportunities for these practices, and it is a significant, well-rounded way to support children's development and learning. Including STEM, a 21st-century learning skill, in the early childhood setting pairs the natural ability of young children to explore their world with a way for children to apply and use concrete methods. With exposure and knowledge of how to integrate STEM in the early childhood classroom, teachers support and implement a more hands-on approach to learning. Consequently, young children are able to take true meaning from what they have learned and apply it. Early childhood educators have many choices for where and how to provide rich, up-to-date STEM teaching and learning. Internet and in-home programming resources, as well as community STEM programs featuring children's "hands-on minds-on" discovery, are available. Such fantastic resources as museums, parks, and family recreation centers exist; in addition to resources such as these, partnerships with families and the community and engagement with organizations that offer support and outreach programs in STEM are great opportunities for teaching and learning stemming from hands-on experiences.

5. Conclusion

The study concludes that the integration of STEM education into early childhood education in Indonesia is significantly advantageous to PAUD development. The findings from the research demonstrate that Indonesia, being the world's fourth most populous country, is taking progressive steps in technological and economic advancements. To accomplish this ambitious target and guarantee the sustainability of the country's progress, a solid foundation starting from early childhood education is crucial. Therefore, measures have to be taken to start to integrate the STEM approach in early years settings. Through the findings and discussion, it is proven that the current practices of early childhood education in Indonesia do not strongly reflect the principles and practices of STEM. However, the qualitative results of the research found that the educators and the related stakeholders responded positively towards the idea of integrating STEM in the PAUD settings. This signifies that there is good potential for STEM to be initiated and learned from a young age. It is essential that teachers be aware of and ready to accept new teaching strategies so that they can tackle the challenges in their teaching routines. The Ministry of Research, Technology, and Higher Education in Indonesia may look to provide high-quality professional programs to promote teachers' innovative and technological advancements in classroom teachings. The study also recommends an initiative to actually develop a curriculum that can be designed to capitalize on the student's natural curiosity and their inherent desire to learn about the world and how it works. This will assist educators in coping with the challenge of developing intentionally designed activities and learning environments to capitalize on children's unique abilities and interests. Meanwhile, in the quantitative analysis, it is revealed that the STEM practices had a significant effect on the teachers' pedagogical practices. STEM teachers were considered to be engaging in more developmentally appropriate classroom practices than non-STEM teachers. This reminds the policymakers or stakeholders that when the teachers are facilitating and engaging the children to learn and express themselves in many creative ways, children can develop in many areas, including social and emotional skills, physical motor skills, language and communication skills, and approaches to cognitive learning. For instance, children will be more confident to ask questions and explore and try out new things

when the teachers provide them with cognitive and creative learning opportunities. In conclusion, the research found a strong positive relationship between the STEM integration practices and the quality environment in PAUD. The qualitative and quantitative findings from individual group interviews and the survey study anchor and complement each other. It suggests that children's learning will be enhanced if they are presented with learning environments and interactive experiences suited to the growth of different components of early childhood development. This indicates that the quality environment with the integration of STEM education will be able to promote great science learning experiences for children in Indonesia. Last but not least, the research holds some value and contributes to the field of early childhood education. It serves as an initial step to start recognizing the implications of STEM practices and how they can benefit early childhood education. The findings may help to guide future reform initiatives for early childhood science education. This study was conducted as a complete fulfillment of the requirements for the Master of Education (Early Childhood Education) program under the researchers' partnership with SEAMEO by providing a professional development program to early childhood educators in Southeast Asia and the Pacific.

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