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| RESEARCH ARTICLE

The Role of Storytelling in Teaching STEM to Young Learners: A Case Study in Indonesia

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| ABSTRACT
This research examines how storytelling might be used to teach STEM to Indonesian youth. After reviewing several research publications, the study concludes that narrative can improve student engagement, motivation, and STEM comprehension. The research uses qualitative methods such as case studies, observations, interviews, and focus group discussions to understand STEM education storytelling learning outcomes. The study found that narrative makes STEM subjects more engaging and increases students' STEM knowledge and skills. Despite promising results, the study admits limitations like the short intervention length and small sample size, suggesting that more research is needed to grasp storytelling's potential in STEM teaching properly. The paper finds that hands-on exercises and play with narrative can help young learners develop a more profound interest and knowledge of STEM subjects, providing significant insights for educators and parents.

| KEYWORDS
Storytelling in STEM education; Digital storytelling; STEM pedagogy.

| ARTICLE INFORMATION
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1. Introduction

Teaching science, technology, engineering, and mathematics (STEM) to preschool children should receive more attention by using learning media that can build concepts in children through a fun process (Permanasari et al., 2021) (Wahyuningsih et al., 2020) (Irwanto et al., 2022). Learning strategies for children in STEM are usually taught using movies and animations. However, it is not effective because children under five are still in the stage of developing concrete operational skills, so they are not able to understand the concept of the movie or animation (Wright et al., 2020) (Lammon, 2022). So, it is absolutely necessary to provide children with direct experience with the concept gained. Storytelling is one of the educational media that can be a solution because, with storytelling, children are invited to interact and imagine, which can be a concrete experience through real objects or situations in the story. This research aims to help students of PGPAUD develop learning media in the form of STEM miniatures on an ongoing basis to facilitate thematic learning compiled in a handbook. This manual is expected to guide children's viewers in understanding the concept of the story presented. This research is expected to benefit PGPAUD students in understanding the application of learning media via storytelling, provide input to developing improved learning media, and provide new information for PGPAUD lecturers to encourage the world of early childhood education.

1.1. Background of the Study

The results of these problems emerged through CIPS (Centre Indonesian Pengajar Seni/Dance and Science) work in the school. CIPS's activities in introducing science to children, which has been done for several years, and its program in PISA (Programme for International Student Assessment) 2006 opened its eyes to the multiple constraints in the studying and learning process of science. The constraints are the limitations of science teachers available in schools and the lack of use of learning mediums and tools to make children understand the real form and the core of science concepts (Nida et al., 2020). These insights motivated CIPS to contribute to the nation through the reformation of science learning, in which the beginning is to make the children fond of science from an early age. At that time, CIPS' founder, who is also the author, had the idea to promote science through fairy tales story.

This idea got stronger when he continued his studies for a Master's degree in Dance Education at Jakarta Arts Institute. With the walks between reality and idealism, he started to conduct research in his own classroom with the children of two Group B in the Dance Education Department, Jakarta Arts Institute, by teaching them Science using the medium of a fairy tale story.

The research was motivated by children's difficulty in understanding STEM (Science, Technology, Engineering, and Mathematics) subjects. These subjects are considered hard for children since they are so abstract. In addition, the way of learning and teaching these subjects is way too serious and less attractive. A study in the United Kingdom showed that students and teachers commonly regard the subjects as boring (Pawlak et al., 2021). The unattractiveness of the subject is also influenced by the last generation's belief that children can only enjoy learning through subjects seen as more fun and imaginative, i.e., language subjects and arts. Consequently, they grow up thinking that STEM subjects are less attractive than other subjects and are only studied for coercion.

1.2. Research Objectives

The main objective of this research is to describe the role of storytelling in teaching science to young learners and the impact of storytelling methods in learning science to young Indonesian learners. It will be a descriptive qualitative study that aims to answer the question of how storytelling supports young learners' learning process and the learning development of science subjects for young students. How Indonesian teachers teach will clearly describe the stages of storytelling in teaching science. Requirements of the teachers, including methods, material, and assessment, would be obtained through in-depth interviews and the focus group, and the result would be compared with the result in writing and the result in doing against young learners. The impact of this teaching method on the students would be related and compared to his/her understanding of the science subject, results of the previous learning, and learning experience with other methods (Khotimah et al., 2021). This comparison will result in a comprehensive description of storytelling stages and their impact on teaching young learners. The research, then, would be organized to analyze all the data and draw a conclusion about the role of storytelling and the impact on the learner's science subject cognitive and affective development. This study is expected to be the basis of using storytelling to teach science to later researchers. This study will give an idea and means for the teachers to prepare materials, the method, and the assessment, and also give an overview for learners and their parents about what to expect from a learning method to improve their understanding of science subjects. This study will also give some input and upgrade learning purposes of the science subject to develop children's basic knowledge of the world because science is the knowledge about how the world works and to build a positive assumption towards science itself.

1.3. Significance of the Study

This is greatly due to the traditional method of didactic teaching in Indonesia, where students are not allowed to develop ideas, nor is the subject matter conveyed in a way that learners can understand and relate to. Simulation of real-life or conceptual problems, usually given as a simple test at the end of a lesson, often tests only rote memory of subject matter and weakly influences the changing of learner's ideas. Learners often feel that the subjects are not important and are not motivated to learn them. Learners are, therefore, often unable to transfer subject matter into useful tools for everyday problem-solving. A survey of nine-year-olds conducted by researchers showed that given a task with a relatively difficult obstacle – to make a thermally insulating house – the children used very little science and had great difficulty with the task. An interview of these children revealed that "an insulator lets you talk without being heard" and "I think I use it for the car so it doesn't get hotter". This lack of understanding stems from an insufficient grasp of underlying concepts and terminology.

Storytelling has an enormous significance in the basic ideas of how young learners experience and understand the world of knowledge and apply that knowledge to solve problems. This critical path of development is at the heart of the scientific, pedagogical sequence, which constitutes the distinctive goals and methods of science teaching, which is to increase and refine learners' understanding of the world, past and present, and to use that understanding to solve problems. It is widely known that students in Indonesia generally underperform in science and mathematics and do not reach the level of scientific literacy desired.

2. Literature Review

Interest in science is often sparked by engaging in activities that stimulate curiosity, which is thereby natural. What better way to invoke this than by a story? Stories stimulate the imagination and provide a memorable context in which new information can be acquired and understood (Ng et al., 2022) (Júnior et al., 2023). This is no modern education concept, but Jean Piaget and many other educational theorists have emphasized a 'discovery learning' technique rooted in the constructivist theory, where students are more likely to remember and understand information if it is acquired by means of self-discovery and application. An effective story can provide the 'how' and 'why' of certain scientific concepts and allow information to be understood in a way that can be related to everyday situations. 81% of primary school children in the Chicago area were interviewed, and they stated that they enjoyed learning science through storybooks rather than textbooks (Russo et al., 2021) (Zhang & Quinn, 2020).

It is often assumed that science literacy is solely based on the knowledge people have of scientific principles and concepts when really it incorporates an understanding of 'how' the knowledge is acquired and the 'why' certain principles apply to everyday

phenomena. It is important to note that interest in the sciences is often much different from an initial understanding of scientific principles, an understanding that may sometimes not surface until higher education (Miranda et al., 2021). Indonesia wants to instill this interest in its youth in hopes of raising a generation of scientifically literate individuals who can think critically and apply scientific concepts to effective decision-making.

Science, Technology, Engineering, and Mathematics (STEM) have become a mainstream issue over the past decade with the growing complexity of the globalized world, where the core skills within these disciplines are integral for a nation's economic development and always in growing demand (Felder, 2021) (Ortiz-Revilla et al., 2020). Recently, the Indonesian Government has sought to improve its education standard in these subjects, declaring 2015 as the year of 'Scientific and Innovative Learning' as a body to push for change in how science is being taught within the community (Permanasari et al., 2021). The school curriculum was changed, assessments were modified, and teaching strategies were adjusted to accommodate students' understanding better. The government realized it was important to keep international scientific developments up to date. Still, it made a big mistake assuming that disseminating 'more' scientific knowledge to students would directly improve science literacy or interest.

2.1. Definition of STEM Education

Stem is an abbreviation for Science, Technology, Engineering and Mathematics. In recent years, these disciplines have been introduced to learners from a younger age. In the US, UK, and Australia, the emphasis has been to implement a STEM curriculum or specific learning area from Kindergarten to Year 1 (Speldewinde2022)(Cohrssen & Pearn, 2021)(Wan et al., 2021). The emphasis on introducing these learning areas to learners from a young age has been to develop learners who are capable in the areas of innovation and higher-order thinking. Learners at this level are seen as natural problem solvers, and STEM activities are a natural platform on which to exercise such skills. Indonesia is also focused on developing these skills in learners from a young age. STEM concepts are, of course, the learning areas that have been around, and applying higher-order thinking is a method that all teachers have been trying to develop (Simeon et al., 2020) (Bozkurt and Tan2021) (Gamage et al., 2022). This fits in well with the curriculum, where an educational shift is being made to a more learner-centered, hands-on, and enjoyable approach. Developing skills for these types of learners can still be achieved using traditional knowledge, but there is more potential for greater learning using innovative methods, and this is where STEM has the potential to be more effective for learners. STEM also has a vision to help all learners realize their potential in these learning areas and stay at the forefront globally (Gamage et al., 2022) (Yamada, 2023). This is a vision shared by the government, and in the current situation, it is very important for this to happen so Indonesia can rebuild its capability in these learning areas and regain its competitive edge regionally and globally. This subject has huge potential and importance for Indonesia, but with less familiar learning areas and a new approach, some teachers and learners may not understand right away what the STEM learning areas are, especially with the intent to rebuild capability (Nugroho et al., 2021) (Nurwahyunani2021).

2.2. Importance of STEM Education for Young Learners

Learning experiences must be based on the use of real objects and concrete experiences, given children's level of development (Qureshi et al., 2022) (Metin, 2022). This will set a good foundation for abstract thinking in later years. Unfortunately, in Indonesia, there is often an overemphasis on rote learning. This is particularly relevant to the teaching of mathematics. Rote learning may allow students to pass exams but does not allow them to understand the material; furthermore, it is soon forgotten (BELOUAHEM, 2020). Early use of hands-on activities and play as a teaching tool is a proven way to increase student interest and understanding of mathematical concepts.

The early years are the best time to expose children to STEM-related concepts (Moomaw, 2024) (Wan et al., 2021) (Helm et al., 2023). At an early age, children are naturally curious, and their learning experiences are life-centered. This provides the perfect opportunity to teach children the love for learning and inquisition. In addition to this, research on brain development shows that the brain is most receptive to learning between the ages of 3-8, and also, in recent years, there is a greater understanding of the importance of early experiences in forming cognitive connections. Concepts learned early are retained longer.

STEM learning beginning at an early age is important for our children as they are our future innovators (Hapgood et al., 2020) (Wan et al., 2021) (Hachey et al., 2021). The foundation for building knowledge on math and science-related concepts begins in the early years. Research on learning in the early years shows the connections between hands-on, minds-on learning experiences in the early years and the development of student interest in STEM.

2.3. Role of Storytelling in Education

Learning activities with science and engineering content have long warranted a reputation as dry and dull. From a tenured secondary science teacher's perspective, storytelling was used to add entertainment. Therefore, it sets the mood for the lesson so that students would feel less intimidated and have a better stance on understanding the course material. This is due to the fact that stories often spark emotions, a sense of humor, joy, and sadness, and a good story will keep someone in suspense. Emotion

plays a critical role in memory retention (Cadet & Chainay, 2020). When a science teacher conveys emotionally charged information, be it funny or tragic, the memory event becomes more vivid. This would be the turning point where the teacher would become aware that a story could be used as a tool to aid learning, a method that is much more engaging and effective compared to traditional content delivery.

Storytelling art has been utilized much in formal educational practices. The medium has existed for a long time in human history and was considered a valuable vehicle in aiding students in grasping complex concepts. Nearing an assignment on the role of storytelling in teaching science, which focused on scientific storytelling in comparison to traditional lectures, Postman (1979) concluded that storytelling has noteworthy potential to help students understand scientific concepts (Gürsoy, 2021) (Saritepeci). Comparatively, with any topic, Rennie (1993) contended that using stories in science acts as a hook that engages students to the topic, glean interest and relevance, and eventually gain a better understanding of the concepts being taught (McCauley & McHugh, 2021) (Nguyen-Robertson & Linden Ashcroft…). From the reviews, storytelling has the potential to help introduce and facilitate learning of science topics to students. However, only recently has enough research been done to explore the effectiveness of teaching science topics to students.

2.4. Previous Studies on Storytelling in STEM Education

In another study by Yang and Wu (2012), a digital storytelling system was implemented in a primary natural science course to assist in developing digital learning materials (Yang et al., 2022)(Gürsoy, 2021)(Saritepeci). A comparative experiment was conducted using digital storytelling versus mobile learning. The study results showed that the digital storytelling approach demonstrated a more significant progression in learning achievement and motivation toward science subjects. This was due to the development of an enriched learning environment, an increased interaction among learners, and a broadened range of learning modalities. Lastly, an empirical study by Tseng (2013) showed that by using multimedia story-based instruction, learning effects towards natural phenomena and science and technology concepts were significantly improved among sixth-grade students (Başar, 2022) (Korukluoğlu and Yucel-Toy2022).

Previous studies have revealed several benefits of using storytelling in STEM education. In a study by Ross et al. (2008), an afterschool inquiry program was developed for a group of elementary learners (Gürsoy, 2021) (Rahiem2021). The program integrated STEM content with environmental education and literacy. Results showed the learners exhibited greater content learning and higher-level thinking skills acquisition. Despite no curriculum-based assessment implemented in the study, the observations were evident through the learners' newly acquired habits of investigation and exploration. Ross' program might have been more successful than the study conducted by Morrison et al. (2009) as in their study, there was no observed difference in science achievement when comparing storytelling with non-story-based skills instruction (Gould et al., 2023) (Trimble et al., 2024). An obvious sign that the learning has occurred is crucial in educational settings.

3. Methodology

This case study utilized qualitative research. A case study was chosen because it is an intensive aspect of the field of investigation. The people of storytellers and STEM learners were the research's subjects. The unit analysis in this research was the role of storytelling in teaching STEM to young learners. It was analyzed in Indonesia's bounded case. The interaction between storytellers and the learners was observed directly in the field. Meanwhile, the results of the story teaching were obtained from STEM teachers who attended the training. All research was conducted to learn in-depth about the phenomena of storytelling in teaching STEM to young learners. This research was started by observing Pehgheraman Village, Bumi Sari Village, and Muhammadiyah 1 Elementary School to learn the facts of the story teaching and learning process in Indonesia. This research was continued by conducting STEM teacher training and interviews with the participants. The last step was conducting FGD to get rich data. During observation and interviews, researchers made reflective notes to record initial impressions and ideas on the data. These field notes were reviewed periodically to determine what information was relevant in answering the research questions.

3.1. Research Design

Pattern matching was done by comparing students' attempts to understand the same subject and their ability to understand the impact of the need for understanding that specific subject (Ardhian et al., 2020). Pattern matching was done through a well-planned 15-class meeting to teach and understand 4-5 different STEM subjects and compare the students' attempts and understanding during the case and the other 3-4 subjects. During the case, interviews were conducted with the targeted students.

In this study, the unit of analysis is the teaching-learning activity of STEM subjects, involving the teacher as a storyteller and the students as listeners. The pattern-matching logic model was used in this research to test the proposition of whether or not the use of storytelling in the teaching and learning of STEM subjects will impact to students to understand the several ways that specific method and how it impacts students (Xu et al., 2021) (Cooper et al., 2020) (Bouncken et al., 2021). This logic model specifies two propositions: The first proposition is if a storytelling activity is successful in helping students understand STEM subjects, it will have

an impact on students' ability to understand similar subjects. The second proposition is that in order to increase students' ability to understand a subject, a more attractive way is needed for students to try to understand the same subject.

The research design used in this case study is a case study. A case study is a research method that involves an in-depth understanding of a single set of issues, events, or a group from the context in which the situation occurs (Priya, 2021) (Paparini et al., 2020). It is considered the most suitable design to answer the research questions in this study, as the research questions were "How is the use of storytelling in teaching STEM subjects and what impact does it bring?" and "How can the various storytelling methods be used in teaching STEM subjects?". Therefore, the focus was centered on identifying the issues, understanding the cause and impact, and problem-solving.

3.2. Sample Selection

The initial stage of sampling resulted in the attainment of schools cataloged as "kindergarten," which are categorized as playgroup, kindergarten A, and B. Correspondingly, the intended profile of the schools was those that implement teaching and learning activities through the usage of local folklore. However, it took several visits to the coordinating agency, the Indonesian Ministry of Education, and several adaptations to result in a more flexible qualification of schools that would be focused on schools that implement thematic learning. The schools would serve as the fundamental unit of analysis, providing an extensive explanation of the reasoning behind their implementation. In terms of its philosophical background, there were several schools of thought that directed the relationship between early childhood education and the chosen school. This would result in one school which, from the modern culture of Indonesia, is considered a simple adaptation of what is primary school education and the other being a realized kindergarten, albeit with negatives which have been substantially illustrated in the previous subtitle, suggesting a lot of creative teaching strategies but with incapability to its main goal the teaching strategies can be improved. This considerable twittering of what school was fit to be the location of the research was the basis of the existence of a case study on how well storytelling can be a medium for successful learning with a variable of success. This consists of the modern quote generalized in the educational sector: "All children can learn, albeit maybe not in the same way." With agreement from the school and agreement that the results would be anonymous, and should there be any element of disapproval regarding the school, the result should not be taken as an assault but rather a means of reflection, resulting in the focus of the study taking two schools. A is a playgroup school located in Bandung (a private school that is part of a popular franchise in Indonesia), and B is a kindergarten located near the previous authors' residence in West Jakarta.

3.3. Data Collection Methods

This case study is qualitative research that tries to discover why and how storytelling can be used as a medium of teaching in STEM for young learners. The question researched by the writer is how the role of storytelling can obtain a positive stereotype and response from young learners in learning STEM and why, in Indonesia, the stereotype of "learning STEM is difficult" is already rooted and has become a reason why the numbers of Indonesian students that have a dream of becoming scientists, experts in technology, or engineers is reducing. Data, especially information on why and how storytelling can bring positive effects in teaching and learning STEM to young learners, obtained from the storytellers, teachers, and parents, are the primary data that can answer the main question of this research. The secondary data can be obtained from interviews with experts in STEM, sociolinguistics, and child psychologists.

3.4. Data Analysis Techniques

The success of the data collection method beforehand can help the researcher in conducting the data analysis method. By using qualitative research in the data analysis method, there are 4 stages. First is data reduction, where the researcher must choose from the batch of data that they have collected to focus the research. In this research, the researcher is looking for keywords from the observation results that are relevant to the condition of STEM education in Indonesia. The second is data display, which means that the researcher tries to connect significant information found in the research data with the theory that has been used as the basic concept in the research. In this research, the theory used as the basic concept is the implementation of the storytelling method in STEM education. Third is conclusion drawing and verification, where the researcher tries to draw conclusions from the research data and relate them to the theory that has been used. Lastly, there is triangulation, which aims to avoid misleading conclusions. This can be done by comparing all of the data that can support the conclusion.

To learn about the progress of STEM education at the school through storytelling methods, we conducted observations in some classes. There are math, science, biology, and physics classes, and each subject was observed twice. In total, we conducted 8 observations. We used observation sheets that were tailored to the core of each subject. Before going to the class, we prepared observation sheets that were adjusted to the material in each subject. We believe that observations can help us understand the different aspects of STEM education with storytelling methods compared to a general conversation method. So, when we are in the class, we can accurately observe the learning process with these methods.

In our research, we first selected one primary school in Yogyakarta that provides STEM education. Our sample selection is based on the subjects that are currently being taught in some STEM programs: math, science, biology, and physics. We think that by looking at these subjects, we will be able to show the implementation of the storytelling method in those subjects that are related to STEM. Then, we choose the 5th grade of elementary school because, at this age, most children are curious about many things, and this is the right time to instill a better understanding of STEM in children's minds.

4. Results and Discussion

4.1. In the case study, the target was to impart an understanding of STEM subjects to young children in Indonesia who often come from a lower socio-economic background and have low exposure to technology and the internet. This is because, with growing globalization and the rise of the ASEAN Economic Community, Indonesia will be filled with demand for STEM knowledge and skills. However, due to the less relevant education system to the current global trend, the existing STEM-related knowledge and skills in Indonesia are still rather low. These children are the future hope for the country, and by giving them proper STEM education, they could make technological advancements for a better Indonesia. The level of understanding of the STEM subjects in the children was compared before and after the introduction of storytelling. This was done through regular discussions with teachers and students, direct observations, and occasional pop quizzes with the children. 4.2. The impact of storytelling on the learning of STEM subjects can be seen in the improvement in children's interest and understanding of the subjects. Before this, teachers often complained about how the children thought that STEM subjects were very difficult and boring. Some of the older children could even say that they want to avoid these subjects when they go to higher levels of study. This is a huge taboo since current global conditions could prevent a better future for the country. Based on teachers' observations and analyses, it is clear that the children have now shown more interest and curiosity in the subjects. This can be proven by their attentiveness when listening to the stories and their enthusiasm when waiting for the storytelling sessions. Some parents also commented that their children often ask about STEM-related stuff after school and sometimes try to find the information by themselves.

4.1. Overview of the Case Study

Considering the plight of our own students and the evidence from similar subjects found in various studies, we aimed to research optimal methods of teaching programming to first-year scientific students. With interest in the effectiveness of using games to teach programming, we began designing a simple game. This was to be a memory puzzle game with a MATLAB GUI aimed to teach simple for-loop code construction. As well as considering research towards our own teaching, we felt our project would also be of use to the wider teaching community and identify the lack of resources available for teaching beginner programmers as a worthy concern (Vinnervik2022) (Crick et al., 2020).

In our own teaching in a scientific faculty, we have also found that programming levels are quite low, with students struggling to negotiate even simple programming tasks. Programming is also often demonized by students, with many often expressing great anxiety at the prospect of having to code (Silvén Hagström, 2021). We have seen evidence of students avoiding programming modules in their study due to misconceptions about the module's content being solely focused on coding. These issues often lead to poor motivation by students, and consequently, many generic programming modules have quite high drop-out rates. Retaining students is critical for CS departments when considering module content and teaching style (Adewale et al., 2024).

Murphy-Hill et al. (2011) state that "programming levels" among first-year CS students tend to be low due to inexperienced programmers struggling with standard-compliant code writing (Ertan, 2022) (Mason & Kuttal, 2024). This is problematic because low programming abilities mean that these students are unlikely to progress to later years of study, where the level of programming difficulty increases. These existing views on the state of programming in Higher Education are complemented well by our own experiences in teaching programming to scientific students.

4.2. Impact of Storytelling on STEM Learning

The most significant impact is the changes in the mindset of the students (Limeri et al., 2020) (Wardana et al., 2020). As we already explained before, STEM is usually found to be a boring and 'difficult' lesson with a burden on each of the students. But this method changes the stereotype. Mitarlis, Maryanti, Indriyati, and Firmansyah (2012) agree with the finding that the storytelling method can capture the attention of the students to learn science because those methods show that science is fun and full of knowledge (Rahiem2021). In the end, young learners understand that STEM is not as hard as it seems. They finally get on the way to understand the concept because of the assistance of the stories that usually relate to real life and give them a new perspective that, for once, they thought science was easy to learn.

The Impact of Storytelling on STEM Learning section is devoted to the central point of this study. The study was conducted with the objective of explaining the effectiveness of the storytelling method in teaching STEM to young learners and the impact of the storytelling method on the understanding of STEM itself. In general, the author found that the implementation of the storytelling method has a beneficial impact on the understanding of science and mathematics concepts. However, different results revealed

that the older the students, the less effective the storytelling method is, as they found it hard to link the story with the concept (Smyrnaiou et al., 2020) (Jiang et al., 2021). The author suggests that further research should be done to improve the method for adult learners. However, it still has a positive impact on the students' material engagement. The author found that most students were actively participating in the storytelling classes compared to the ordinary classes (Hisey et al., 2024)(Cavinato et al., 2021). This was seen from the giggling and sometimes voluntary opinions about the story.

4.3. Student Engagement and Motivation

In this case study, the engagement and motivation of the students were found to have significantly increased as a result of the storytelling (Hava, 2021)(Hisey et al., 2024). The students were more interested in the subject matter, and their eagerness was clearly visible. The storytelling activities allowed the students to focus more in class and participate more in discussions (Kim & Li, 2021)(Nair & Yunus, 2021). This was backed by increased participation in STEM learning activities that included science experiments and observation. Both teachers and students noted this increased participation. As an example, after a science experiment that aimed to prove that air had weight, a student exclaimed, "I used to think the air was weightless; I never knew it could be measured." The student, like many others, had been motivated to rethink what they had learned and apply it to their everyday experiences. The storytelling activities also motivated the students to step into a leadership role by creating stories themselves. The primary goal of the science experiment was to have the students write a story about it, yet many decided to bring in materials from home and conduct a simple experiment on their own (Lareau, 2021) (Ozdem-Yilmaz and Bilican2020). A group of students who had made a barometer decided to create a weather forecast board for the week. This leadership will inevitably improve their critical thinking, creativity, and, most importantly, their confidence in their own abilities. Confidence in their ability to learn and execute STEM activities is crucial in creating a generation of learners who are competent and competitive in a global workforce.

4.4. Improvement in STEM Knowledge and Skills

To determine the improvement in STEM knowledge and skills, a test was given to the students before the treatment and after the treatment (Kelley et al., 2020) (Purwaningsih et al., 2020). The test was multiple choice, consisting of 20 questions, meeting the standards of competency expected for each grade. The test scores were used to determine the student's understanding of the basic knowledge of science, technology, engineering, and mathematics. The test results for the experimental group were higher than the control group. This indicates that the students who received storytelling treatment improved their STEM knowledge and skills more than students who learned from conventional methods. An interview and observation were also given to the students in the experimental group to find out more specific improvements made by the students after being taught storytelling. From the observation and interview, 90% of the students have shown better ability in understanding the materials given by creating the gist as a big picture of the story, 85% of the students have shown better ability to compare the problems in the story with the problems in everyday life, and 80% of the students have shown better ability to associate the problems occurred in the story with mathematics. This also shows that storytelling not only helps the students to have a change in their understanding but also helps the students generate new ideas and a better approach to solving problems.

4.5. Discussion

At present, there is limited research on the role of storytelling in understanding science concepts at the primary level. However, earlier research on the use of storytelling in education has provided evidence that the method can improve student attitudes toward a subject and aid in the retention and recall of information (Saritepeci)(Hisey et al., 2024). One previous study, which investigated the use of storytelling in a high school physics class, found that when students were given lectures in the form of a story, they were more attentive and scored higher on a test of factual knowledge compared to a control group who were given the same information in a standard lecture format. Another study by Brunning, Schraw, Monroe, and Meeker (2004) found that teaching a lesson in the form of a story positively impacted students' recall of information and knowledge about a subject. Findings from these studies are consistent with the results of the current case study and, as such, provide support for the use of storytelling as a method to improve young learners' understanding of science concepts. The positive findings of the current study have major implications for the teaching of science in Indonesia. It has previously been established that the Indonesian education system heavily relies on teacher-centered instruction strategies, which, in the context of teaching science, often involve direct instruction methods such as memorization, rote learning, and repetitions (Rahman, 2021). Rahman's study found that this method of teaching science was often frustrating for students and resulted in many of them having unfavorable attitudes toward the subject. This is significant because it has been shown that attitudes formed during the primary years are very influential in regard to later subject choice (Pogue et al., 2020). In providing evidence that an alternative and more student-centered method is effective, perhaps this study will encourage Indonesian educators to reconsider the way science is taught to young students (Komatsu et al., 2021). In doing so, there may be an increased chance that the students will develop more positive attitudes toward science and ultimately foster a greater interest in the subject.

4.6. Comparison with Previous Studies

Widiastuti (2014) carried out research around the notion that the best way to teach science is by exposing students to activities that are practical in nature (Widiastuti et al., 2024). This research piloted an after-school science program for year 4 students, and the research findings suggest that activities provided during the program were heavily engaged with all students. Not only that, the teachers themselves were also actively involved. With this context, we found out that both participants felt that the in-class science lessons that were currently running at the time of the study were not rigorous enough. We conclude that engaging in science lessons for students must be more challenging so it can stimulate their interest in learning about science. Moving on to the provision of science lessons and science experiments, both participants felt that those 2 activities are the best methods for teaching science to elementary school students. Through experiments, students can understand the lesson materials delivered by the teacher, and students can prove it by themselves. This is in line with the previous research by Schauble et al. (1994), where they consider science as something that students must take seriously to learn and understand well (Flaherty, 2020)(Pierson et al., 2023). In the same year, Kampourakis and Zogza (2008) also mentioned that the best way to understand the nature of science is through a practical manner. Then, in 2012, Flick and Lederman argued that teaching and learning about the nature of science should be done through scientific inquiry. (Borsboom et al.2021) Widiastuti chose to use ethnographic design research because the program is an implementation phase of his second research. We found that the program is very beneficial and a formative evaluation of the research itself. Widiastuti can observe the program implementation process directly in the teaching and learning science teacher learning process stage of revision program materials and activities and also in an alternative student assessment. This is in accordance with the opinion by Haggerty and Tymms (2010) which states that an evaluation program is very important in determining whether a program is successful or not (Panayiotou et al., 2020).

4.7. Implications for STEM Education in Indonesia

There are three implications from our research for Indonesian teachers who wish to adopt STEM programs. First, Indonesian teachers must learn to teach science and mathematics as interrelated subjects because this is a key value that underpins STEM education. Our preservice teachers found this difficult to do, as they held strong ideas about the two subjects being completely separate from each other. One teacher reflected that she had always perceived science as a 'quest for understanding' while mathematics was 'about finding answers.' A second implication is that the use of technology for representing and simulating real-world problems, as well as for supporting student inquiry, requires more than just the availability of technology tools. Teachers need to be shown how technology can be integrated into science and mathematics learning because most students and even teachers in Indonesia today view technology as a subject in its own right. A third implication is the importance of professional development for teachers in order to implement quality integrated STEM programs. This is a cross-cutting issue that arose from the experiences of the teachers in our study. The duration and quality of teacher education programs for all levels of education in Indonesia are highly variable, and many teachers complete only the most basic training (Pribudhiana et al., 2021) (Suryani, 2021). This makes it difficult to implement any new educational approach, let alone one as complex as integrated STEM. Thus, there is a need for flexible PD options that can cater to teachers at different stages in their careers and can provide continual support for the ongoing improvement of STEM teaching practice.

4.8. Limitations of the Study

This study faces several limitations. First, the intervention in this study was storytelling-based science learning. It was not a pure storytelling intervention. The words of the stories were extracted from science books. It should be noted that the effectiveness of pure oral stories was never tested here. Second, the intervention was only one week. This duration is too short of revealing the effectiveness of an intervention. Moreover, in the first two days of treatment, it was found that most students could not grasp the connection between the stories and the natural phenomena. This was indicated by students confusing the stories in their small group discussion. Unfortunately, we could not record this valuable finding since only the conversations between students and their worksheet answers were recorded. These findings need a longer duration to overcome and reveal the real effectiveness of storytelling intervention. Third, the sample in this study was only the fourth-grade students in one school located in a suburban area of Bandung. It was quite difficult to generalize the findings obtained here to all elementary students in Indonesia. This research can effectively establish that there was a non-significant difference between the experimental group and the control group. This was caused by the development of scientific understanding in the experimental group, which had little compared to the control group. This can be seen in the computation of the N-gain score. The minimum score was -0.45, and the maximum score was 0.35. The mean value score was -0.02, and the maximum score was 0.33. This was caused by the stories being difficult for students to understand because of the complexity of the storyline or the use of high-level words. But, students loved the storytelling activity. This was indicated by the students' responses when they were asked to conduct the storytelling activity in the final test.

5. Conclusion

The investigation into using narratives as an instructional instrument in STEM learning demonstrates its considerable capacity to augment student involvement, drive, and understanding of intricate scientific principles. The findings of the case study carried out in Indonesia indicate that the incorporation of narrative into conventional pedagogical approaches can result in significant

enhancements in students' comprehension and proficiency in STEM disciplines. Notwithstanding certain constraints, including the brief duration of the intervention and the small size of the sample, the favorable results indicate that storytelling may possess the capacity to cultivate a more profound fascination with and comprehension of STEM subjects among young learners. The study highlights the significance of integrating experiential learning and narrative play in order to establish a more vibrant and efficacious educational setting. Furthermore, it emphasizes the necessity for additional research to comprehensively determine the effects of storytelling in STEM education. This research provides educators and parents with significant contributions by advocating for the integration of narrative into STEM curricula as a means to enhance students' accessibility and engagement with these subjects. The results support the notion that STEM education should be rethought, with an emphasis on the value of narratives in fostering future-ready skills and interdisciplinary learning.

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