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Enhancing Early Childhood Teacher Pedagogical Competence Through STEAM-Based Instructional Training: An Experimental Study

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ABSTRACT
This study aims to ascertain the effects of STEAM-based instructional training on the pedagogical competencies of early childhood education teachers. The pedagogical competencies of early childhood education teachers in this study include knowledge teacher about consepts STEAM learning and performance teaching in developing teaching modules of STEAM include lesson planning and creating learning media. This research used experimental method. Design experiment used the one group pretest posttest with a sample of 112 members of IGTKI Jember. The training methods were lectures, discussions, simulations, and assignment projects. The training was conducted in the hall of the Education Office of Jember for duration of 12 hours. Data were collected through the cognitive tests about concepts STEAM learning and performance tests about developing ideas of STEAM learning. Data quantitative were analyzed used the Wilcoxon Signed-Rank test and data qualitative were used descriptive analyzed. The results found that training of the STEAM learning model had a significant effect on increased teachers knowledge and skills in STEAM learning with a significance level of 0,000, which is lower than 0,05. The indicators used to assess participant's satisfaction in this training include the training theme, punctuality, material completeness, content mastery, training method, interaction with trainee, and the trainer's attitude. The result found rata 98,5% trainee was satisfied. The observation found that trainee were able to develop STEAM ideas and creating learning media by utilizing materials available in the surrounding environment, and trainee were able to teaching STEAM with the four stages from explore, extend, engage, and evaluate.
Keywords: *Pedagogical Competence, STEAM, Instructional Training*

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INTRODUCTION

Education is one of the fields that has the responsibility to help children master the skills needed in the era of the 0.5 industrial revolution, so innovation is needed in learning activities that are in accordance with the problems and needs of the times (Wulandani et al., 2022). The Indonesian government has developed a roadmap for Indonesian education from 2025 to 2045. One of the key aspects is the development of STEAM-based learning and the improvement of teaching and learning quality, especially in early childhood education (Kementerian PPN/Bappenas, 2025). The national curriculum encourages the integration of literacy and STEAM elements as part of foundational learning outcomes (Widhiharsanto & Akkas, 2023).

The pedagogical competencies possessed by the early childhood education teachers significantly effect the quality of the learning process for children. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning model is an approach that integrates competencies across the fields of science, technology, engineering, arts, and mathematics, moving from interdisciplinary to transdisciplinary (Perales & Aróstegui, 2021). This STEAM learning model offers many benefits, particularly in promoting development in language mastery, understanding, and communication skills (Wade et al., 2023). Additionally, several research studies indicate that this learning model supports early childhood in developing creative and strategic thinking skills.

Competence is the ability to use knowledge, skills, and personal, social, and methodological abilities in work or learning situations, as well as in professional and personal development (Spyropoulou & Kameas, 2021). The competence of Early Childhood Education teachers is not limited to cognitive elements, but also includes technical skills and interpersonal attributes (such as social or organizational skills) and ethical values. Pedagogical competence is a crucial ability that teachers must possess in order to effectively manage classroom learning, requiring them to master classroom management (Martiin, 2018). Pedagogical competence can be assessment through the design and implementation of the teacher's lessons (Millati & R, 2021). STEAM pedagogical competence for educators includes: 1) understanding and applying teaching and learning techniques that support STEAM learning; 2) implementing collaborative learning methods in interrelated activities; and 3) supporting independent learning in STEAM activities (Spyropoulou & Kameas, 2021).

Many countries have adopted this learning model, but teachers still face limitations in knowledge and experience in implementing it. For example, teachers in Lithuania have applied STEAM learning practices to young children, but they are unable to ensure sustainable development of children's skills due to their limited understanding of the learning process (Dolgopolovas, 2021). Moreover, existing data regarding the implementation of STEAM learning for young children by prospective employees and juniors in Turkey acknowledges that there are time and resource shortages, lack of professional development, insufficient knowledge about STEAM, low parental participation, and teachers' reluctance to collaborate (Uraş and Genç, 2018 in Sit, 2022).

One of the programs proposed by the Indonesian Government is the STEAM learning model for early childhood, although teachers' ability to implement STEAM learning still needs to be improved to ensure quality STEAM education. Several studies also show that pre-service teachers or early childhood education teachers need training to effectively implement this learning model (Sit, 2022). For preschool-aged children, the experience of STEAM learning depends on the teacher's ability to facilitate an environment, materials, and challenges that stimulate the children's curiosity (Sirajee, 2022).

The lack of pedagogical competence among Early Childhood Education teachers in the development of the STEAM learning model became a significant issue. According to reports from the teacher working groups under the Indonesian Early Childhood Teacher Association (IGTKI) in Jember Regency, teachers are still struggling to understand the STEAM learning model and its implementation, from planning and creating teaching media to implementation in their schools. Many teachers face difficulties in developing STEAM concepts in their teaching modules, and they still cannot provide learning media that match with the STEAM learning model concept.

Results The evaluation results of the Training Bunda Pertiwi Kindergarten in Medan showed that the challenges faced by teachers in creating STEAM media were 50% due to a lack of references regarding STEAM, 30% due to the availability of tools, materials, and facilities, and the last challenge was the lack of support from the school (Ningsih & Farida, 2023). This indicates that the training objectives should focus on teaching participants about STEAM development ideas, including lesson planning and creating learning media. Other research findings showed that the challenges in the STEAM learning process stemmed from teachers' limited competencies, which hindered the optimal implementation of STEAM in Early Childhood Education learning (Sativa et al., 2024). Correlational studies also showed that teachers with higher pedagogical competencies were able to implement STEAM learning more effectively, whereas those with lower pedagogical competencies had not yet applied STEAM learning well (Adzani et al., 2024).

Curriculum based STEAM for early childhood will motivate children to conceptualize, explore, and develop the use of available educational tools, sharpen their knowledge, enhance their affective development, and apply knowledge in a simple manner. However, teachers knowledge about the implementation of STEAM is still limited (Novitasari et al., 2023).The results of a literature study indicate that STEAM stimulates three areas of child development: cognitive, affective, and psychomotor. STEAM learning activities emphasize learning by doing, providing challenges for children to complete specific tasks that require more time to assimilate new things they learn and apply them in everyday life practice (Novitasari et al., 2023).

STEAM learning does not always require modern materials, everyday items such as blocks, sticks, stones, seeds, paper rolls, milk carton boxes, buttons, and other common materials are highly suitable for STEAM learning (Sirajee, 2022). Another article by Eckhoff also mentions that STEAM experiences involve various types of materials, but the use of commercial and manufactured materials is not necessary (Sirajee, 2022). Therefore, the challenges that teachers face in creating STEAM media, as well as the availability of tools, materials, and facilities for this learning process, can be addressed with teacher's creativity in developing ideas of STEAM using learning resources from the natural environment.

One of the characteristics of STEAM learning is using tools and materials from the surrounding environment, known as open-ended materials, which are engaging, safe, and can be manipulated by children according to their ideas, thoughts, concepts, or imagination. Therefore, these play materials should not be ready-made toys but rather materials that children can creatively modify or manipulate (Hasbi et al., 2023). Additionally, teachers must be able to integrate disciplines based on technological tools and engineering, such as small science laboratories equipped with microscopes, telescopes, magnifying glasses, jars, funnels, room thermometers, measuring tools, scissors, and cutters (Sirajee, 2022). However, teachers require more training for further integration of STEAM across all disciplines.

Another important point is that teachers must competent in the practices and pedagogical methods of learning in nature, incorporating six scientific concepts earth, ecology, interaction, materials, objects, time, and weather (Cutter-Mackenzie-Knowles et al., 2021). Earth relates to the concepts of earth, soil, mud, compost, worms, geography, landscapes, water, air, fire, and land. Weather relates to the concepts of weather, climate, seasons, atmosphere, drought, humidity, rain, heat, cold, global, local, and movement. Interaction relates to the concepts of humans, non-humans, countries, indigenous people, connections, disconnections, dependencies, and attachment. Materials relate to the concepts of objects, entities, organic, inorganic, nature, rocks, plastic, hard, soft, solid, opaque, porous, wild, domesticated, maintained, and messy. Objects relate to the concepts of creatures, humans, non-humans, affective, living, dead, agency, moving, static, virtual, and hybrid. Time relates to the concepts of temporary, permanent, light, dark, day, night, sun, sky, moon, stars, deep time, ancient, dreaming, past, present, future, change, age, era, period, rhythm, and speed. Ecology relates to the concepts of ecologyMart, animals, plants, bacteria, fungi, seeds, germination, pollination, life cycles, energy, flow, systems, biodiversity, living, non-living, stable, fragile, intertwined, growing, dying, preserving, maintaining, regenerating, habitat, and conservation.

Based on the NYSCI's Design-Make-Play approach, teachers must competent about the core framework of each STEAM learning activity, which consists of three main components (New York City Department of Education, 2023). First, the introduction based on literacy can be done using storybooks, storytelling videos, children's interests, natural and man-made materials, and original photos of objects to inspire stories. This initial activity serves as an exploration to spark ideas or imagination in children. Next, the teacher encourages children to discuss new vocabulary they have heard and to ask questions about the topic or subtopics. The teacher presents a STEAM design challenge that arises from the plot or characters in the story. This activity aims to develop language skills, reasoning abilities, and empathy of children. Second, exploration of materials and tinkering (hands-on experimentation). This activity based play, the children explore the properties of materials, how they work, and how these materials can be used, combined, or manipulated to solve problems.

The teacher's role is to provide a variety of materials such as cardboard pieces, food coloring, markers, origami, and other resources. Children are given the opportunity to choose and take the necessary tools and materials according to their needs. They are free to create and make works based on their imagination and ideas as solutions to problems faced by the characters in the story. This activity can integrate science, math, arts, technology, and engineering. For example, children may design and build a bird’s nest using natural and recycled materials. Third, engineering design thinking (making, testing, repeating), the children explore STEAM-based challenges and work together to find ways to solve problems, test their solutions, share their results with each other, and build upon this knowledge to improve or modify their solutions using thinking strategies. This activity builds skills such as in STEAM activities where children assemble natural materials and available resources to create a safe bird’s nest by making, testing, and repeating the process. An example of this is a STEAM activity where children assemble and stack wooden blocks to create a tall structure in order to test dropping a pre-filled egg.

STEAM learning model facilitates four play experiences for early childhood including explore, extend, engage, and evaluate (Tim GTK DIKDAS, 2021). In the explore phase, children explore materials with various senses while the teacher tries to encourage children's curiosity and encourage children to ask questions. For example, the teacher divides the children into project groups, then invites them to walk in nature with the children to collect natural materials such as twigs, branches, leaves, pine seeds while encouraging children to look for objects that birds might use to build nests and instructing them to observe places that birds might use to build nests. The extend phase provides further challenges by inviting children to investigate. The teacher provides open challenges for children to solve problems with materials that the teacher has provided or that the children find themselves (collect) materials around them that they will use to solve problems. Children can do this activity individually or in groups. For example, the teacher provides various natural materials, pieces of cardboard, crepe paper, markers, origami, eggs, plastic, glue, ice sticks, natural materials, and other materials, then the children are given the opportunity to choose and take the necessary tools and materials as needed and the children are free to create works according to their imagination and ideas about strong and safe bird nests. In the engage phase, children are kept involved in the learning experience. For example, the teacher provides a little help to some children who need help using scissors and tape and lets the children decide what and how much to put in their plastic eggs (marbles, coins, miniature toys, paper clips). In the evaluate phase, the teacher provides time for reflection and evaluation. For example, questions and answers about the conclusions of science and engineering experiments and children show the their product's results that they have made and tell about it. The teacher asks open-ended questions about what they have done in learning, how they feel, and what they found during the process of making that products.

Training is defined as an activity to provide workers with the skills needed to perform their jobs (Dessler, 2017). Training and development are central to ongoing efforts designed to improve workers' competencies and organizational performance (Mondy & Martocchio, 2016). Therefore, training is crucial because, even though experienced and new workers may have high potential, without knowing what to do and how to do it, they will end up doing things that are unproductive. This research aims to examine the effects of a STEAM based instructional training on the pedagogical competencies of ECE teachers. The research questions include 1) is there an improvement in teachers' knowledge and skills regarding the STEAM learning concept before and after the training? 2) how does participants' skill in developing ideas STEAM learning model for daily life?.

RESEARCH METHODOLOGY

This research used a quantitative research design with an experimental method. The experimental research design involves a single group of subjects without a control group for comparison. The training participants consist of 112 trainee. The training was conducted in the hall of the Education Office of Jember for duration of 12 hours. They became part of the research sample with the criteria of never participated in STEAM learning model training, active as early childhood educators, and members of IGTKI Jember. The training process uses lecture, discussion, simulation, and project assignment methods. Training structure include:

Table 1. Training structure

Time	Agenda	Method	Outcome
1 hour	Pretest	Cognitive test and performance test	Score pretest
2 hour	STEAM learning concept	Lecture	Trainee understand STEAM learning concept
3 hour	Developing teaching modules of STEAM include lesson planning and creating learning media	Lecture and discussion	Trainee able to develop teaching modules of STEAM
4 hour	STEAM learning simulation practice	Project assignment	Trainee able to develop STEAM ideas and creating learning media by utilizing materials available in the surrounding environment and trainee were able to teaching STEAM with the four stages from explore, extend, engage, and evaluate.
1 hour	Question and answer session about the planning of the STEAM learning program	Discussion	Trainee understand the planning of the STEAM learning program
1 hour	Post test	Cognitive test and performance test	Score postest

The techniques data collection include cognitive knowledge tests on STEAM learning concepts with a pretest-posttest consisting of 14 multiple-choice questions. Psychometric validity and reliability of cognitive knowledge tests involved 15 respondents. The results of the Pearson correlation analysis showed that all items had a significant correlation with the total score of the instrument test. Result SPSS analysis showed they have a significance level of less than 0,05. Then result reliability test with a Cronbach Alpha coefficient value (0,893) more than 0,70 so it can be concluded that the cognitive knowledge tests has high reliability. The result validity and reliability test presented in this study as follows:

Table 2. The result validity cognitive knowledge tests

Items	r	p (Sig. 2-tailed)	Information
Item 1	0,785	0,001	Valid
Item 2	0,549	0,034	Valid
Item 3	0,675	0,006	Valid
Item 4	0,705	0,003	Valid
Item 5	0,736	0,002	Valid
Item 6	0,736	0,002	Valid

Item 7	0,736	0,002	Valid
Item 8	0,675	0,006	Valid
Item 9	0,585	0,022	Valid
Item 10	0,585	0,022	Valid
Item 11	0,645	0,009	Valid
Item 12	0,541	0,037	Valid
Item 13	0,526	0,044	Valid
Item 14	0,579	0,024	Valid

Table 3. The result reliability cognitive knowledge tests

Cronbach's Alpha value	Critical value	Information
0,893	0,70	Reliable

Performance tests on ideas STEAM learning also pretest-posttest, which include 5 items indicators from creating prompting questions, determining sub-elements of learning goals and objectives, concept mapping, steps for STEAM activities according to the concept map, starting with the initial activity (exploration) to spark ideas or imagination in children, skill-building activities, and main activities (tinkering) in science, math, arts, technology, and engineering. Performance test in this study use rubric as follows:

Table 4. Rubric performance tests on ideas STEAM learning

Category	**Poor (1)**	**Good (2)**	**Excellent (3)**
Creating prompting questions			
Determining sub-elements of objectives			
Determining learning goals			
Concept mapping			
Steps for STEAM activities			
Total score= (Sum of Score/15)x100			

Total score calculated. Both of them scores are added and averaged. These score were compared from pre test and post test in order to measure the difference in the increase teacher pedagogical competence that occurs in the before and after training. The conclusion regarding the training effects will be analyzed using parametric or non-parametric test, specifically the Paired Samples Test or Wilcoxon Signed-Rank test, to compare pre test and post test scores. The first analysis data measure assumptions. Parametric test must to meet the assumption of normality data, homogeneity of variances, and linearity but non-parametric test does not rely on these assumptions. Descriptive data analysis is used to analyze the evaluation data from the training process and the results of the observation of the practice group's simulation in developing ideas STEAM learning and practicing STEAM learning simulations.

RESULTS AND DISCUSSION

Pre test and post test data values were tested for normality by SPSS 26 and results of count showed p-value pre-test 0,291 is greater than (α = 0,05) and post-test 0,002 is smaller than (α = 0,05). Based on result this test concluded pre-test data is normally distributed and post test data is non normally distributed. Following tested homogeneity data to see homogeneous and non homogeneous data. Based on mean value 0,000 is smaller than (α = 0,05) so obtained non homogeneous data. Linearity test was carried out in the pre-test and post test data obtained value of deviation of linearity 0,159 is greater than 0,05 so concluded meet linearity. The results test of the assumptions of normality data, homogeneity of variances, and linearity are as follows:

Table 5. Results of the Normality Test (Shapiro-Wilk)

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Pretest	.070	112	.200*	.986	112	.291
postest	.070	112	.200*	.961	112	.002

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 6. Results of the Homogeneity of Variance

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Skor	Based on Mean	15.866	1	222	.000
	Based on Median	15.757	1	222	.000
	Based on Median and with adjusted df	15.757	1	203.432	.000
	Based on trimmed mean	15.848	1	222	.000

Table 7. Results of the Linearity

ANOVA Table							
			Sum of Squares	Df	Mean Square	F	Sig.
postest * pretest	Between Groups	(Combined)	2545.645	39	65.273	1.283	.179
		Linearity	7.869	1	7.869	.155	.695
		Deviation from Linearity	2537.776	38	66.784	1.313	.159
	Within Groups		3662.212	72	50.864		
	Total		6207.857	111			

Therefore non-parametric test, specifically Wilcoxon Signed-Rank test is performed to see the the difference in the increase teacher pedagogical competence that occurs in in the before and after training (pre test and post test scores). The result revealed a significant difference between the scores before and after the training, z = -9,187 is smaller than than 0,05. The ranks table showed that there were no negative ranks (N=0), indicating that no post test scores were lower than pre test scores. In contrast, there were 112 positive ranks (N=112, Mean rank 56,50, sum of ranks 6328,00) demonstrating that all post test scores were higher than pre test scores. These results suggest a consistent improvement in the teachers' test scores pedagogical competence after STEAM based instructional training. Then Asymp. Sig. (2-tailed) value of 0,000, which is less than 0,05, indicates that the STEAM-based instructional training had an impact to increase the teacher pedagogical competence. The differences in median is 36,5000 which means the median increases in scores test with the after training versus the before training is 36,5000.

The results of the Wilcoxon test for pretest and posttest data are as follows:

Table 8. Results of the Wilcoxon Test for Pretest and Posttest Data

		N	Mean Rank	Sum of Ranks
postest – pretest	Negative Ranks	0[a]	.00	.00
	Positive Ranks	112[b]	56.50	6328.00
	Ties	0[c]		
	Total	112		

a. postest < pretest

b. postest > pretest

c. postest = pretest

Z	-9.187[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Report

Median

pretest	postest	differences
52.5000	89.0000	36.5000

From histogram of difference scores, it informs there are all of trainee (n=112) had positive differences , which means there are all of trainee (N=112) gain increase scores test after done STEAM based instructional training. The results of the histogram difference scores pre test post test as follows:

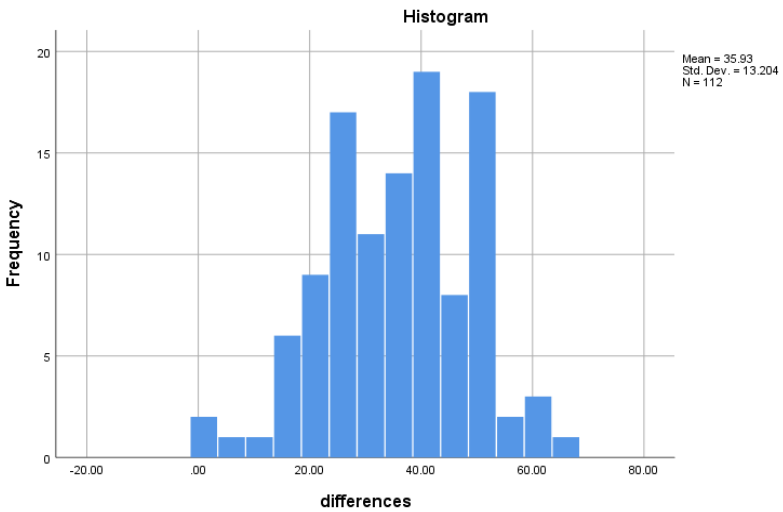

Figure 1. Histogram of difference scores

The evaluation results of the training process, based on the questionnaires distributed by the trainers regarding this training, show a positive response from the participants. The participant's satisfaction with the implementation of the activities received a good rating, with an average score of 46,7% and 83,3% in the satisfactory category. This indicates that participants were satisfied with the activities, as reflected in their positive responses. Regarding the training materials presented by the instructor, the results were rated as good with a percentage of 1,5%, and the overall result was rated as satisfactory, with an average score of 98,5%.

STEAM learning simulation practice provided a dynamic and immersive environment where trainee could explore and apply each of the STEAM components in meaningful ways. The hands-on nature of the training ensured that participants not only obtained theoretical knowledge but also developed practical skills. Trainee integrated literacy, science, technology, engineering, arts, and mathematics into their projects. They were able to create engaging, real-world solutions for understanding the daily life of birds and their habitats, ultimately preparing them to implement STEAM learning in their classrooms.

Throughout this training, each group was encouraged to think critically and creatively as they engaged with the task of helping Mr. and Mrs. Bird with their nest-building efforts. The integration of STEAM components allowed participants to approach the project from multiple perspectives, ensuring a holistic learning experience that reflected the interconnectedness of science, technology, engineering, art, and mathematic. Trainee were organized into several project workgroups and tasked with developing STEAM-based lesson plans that focused on the daily life of birds, specifically bird nests and eggs. This project allowed trainee to integrate and apply their knowledge across the five STEAM components. The assigned lesson plan required trainee to consider how birds build nests and lay eggs, and how these natural processes can be explored through hands-on activities that incorporate scientific inquiry, artistic expression, mathematical reasoning, technological applications, and engineering principles.

First, aspect science. Trainee explored the concept of birds' living spaces, focusing on how different species create their nests and care for their eggs. For example, the group "Mama Inspirasi" discussed the habitats of birds and how they relate to bird behavior and reproduction. They used the natural materials provided to create two types of bird habitats include human-made bird cages and naturally constructed bird nests. This allowed participants to examine the role of natural resources and environmental factors in the creation of these habitats. Similarly, the group "Cicit Cuit" explored the transformation of eggs into chicks, enhancing their understanding of the life cycle of birds.

Second, technology. Trainee were required to transform natural materials into bird habitats. For instance, the group "Mama Inspirasi" used tools and technology to process natural materials like twigs and straw into functional bird habitats, including bird nests and cages. The use of modern tools, such as string, wool thread, and other necessary equipment, helped participants construct their designs and understand the role of technology in shaping the physical environment. The group "Cuit Cuit" also applied technological principles by constructing bird nests and chicken coops with the assistance of modern tools to strengthen their structures.

Third, engineering. Engineering principles were embedded throughout the entire project as participants worked with tools and materials to create functional, well-structured bird habitats. For example, the group "Mama Inspirasi" engineered bird habitats by using specific tools for cutting and trimming, ensuring the durability and stability of the bird nests and cages. Engineering was also applied by the group "Cicit Cuit" when they built a bird nest and chicken coop. They carefully selected materials and used engineering principles to ensure that the nests were strong enough to support eggs, while the chicken coop could house birds safely and securely.

Fourth, art. Art played a significant role in shaping the aesthetics of the bird habitats. Trainee were encouraged to incorporate colors, decorations, and creative designs to make the habitats visually appealing. For example, "Mama Inspirasi" focused on the artistic design of their bird cages and nests by incorporating various colors and arranging the habitats in aesthetically pleasing ways. The group "Cuit Cuit" also integrated art into their project by designing tree flowers where the bird nests were placed. They used different colors to enhance the visual appeal and realism of their project, while considering how the artistic elements complemented the natural materials used in the construction of the nests.

Fifth, mathematics.Mathematics was essential in the planning and execution of the projects, as trainee applied mathematical concepts to solve real-world problems. For example, the group "Mama Inspirasi" used mathematics to measure the size of bird eggs and count the number of eggs in the nests, reinforcing the importance of measurement and numerical reasoning. The group "Cicit Cuit" also applied mathematics by measuring the number, size, and weight of the eggs, which helped them explore concepts like volume, weight, and dimension in a hands-on and practical way.

The group assignment for the STEAM learning simulation practice was conducted using materials provided by the trainer, which included cardboard, wool yarn, sewing thread, cotton balls, crepe paper, markers, origami paper, eggs, plastic, glue, hemp rope, mini plastic bird replicas, screws, large and small marbles, pipe cleaners, ziplock bags, felt fabric, paper clips, plastic tweezers, popsicle sticks, and natural materials (oak tree seeds, dry twigs, and dry straw). Training participants were divided into several project workgroups to develop ideas for STEAM learning model applicable to everyday life, in accordance with the teaching module from the Merdeka Curriculum shared by the trainer (Wulandani et al., 2022).

The assigned topic and subtopic focused on the daily life of birds, including bird nests and eggs. Initially, participants were asked to watch a storytelling video based on the book *The Best Nest* by P.D. Eastman. Subsequently, they filled out the teaching module worksheet by identifying new vocabulary, formulating questions related to the topic, and posing open-ended questions about children's creative projects. Following this, participants were tasked with creating a lesson plan of STEAM encompassing both skill-building activities and main activities (tinkering) across science, mathematics, art, technology, and engineering. Each group was encouraged to freely create projects based on their imagination and ideas as solutions to help Mr. and Mrs. Bird.

Stories can give an inspiration for teachers in developing early childhood play activity plans (Widhiharsanto & Akkas, 2023). Literacy-based introductory activities can utilize video storytelling media to inspire stories. This initial activity stimulates the imagination and ideas of young children, encouraging them to discuss vocabulary (New York City Department of Education, 2023). Subsequently, the team groups filled in the STEAM learning plan framework in their respective teaching modules, focusing on the topic of birds' daily life and the subtopic of bird cages.

The simulation practice for the "engage" and "extend" phases was conducted. The team group "Mama Inspirasi" designed bird habitats by selecting appropriate tools and materials (Magnaye, 2022). During reflection, they shared that from a literacy perspective, they learned vocabulary related to bird cages and nests. From a science aspect, they discussed knowledge about birds' living spaces. In terms of technology, they transformed natural materials into two types of bird habitats: human-made bird cages and naturally built bird nests. The engineering aspect involved using tools and technology to process natural materials into bird habitats, such as using twine made from straw and tree branches, assisted by specific tools for cutting and trimming (Kurniawan & Masnawati, 2022). The art aspect included various colors, aesthetic shapes, added decorations, and positioning of the habitats some were hanging, while others were placed on the ground to make them attractive and harmonious. The mathematics aspect involved counting the number of eggs and measuring their sizes.

Figure 2. The output of the team group Mama Inspirasi
Source: Personal document of the informant (Nur Fatwikiningsih)

The team group "Cicit Cuit" has an idea of design a bird's nest and a chicken coop, positioning the bird's nest naturally above the chicken coop. They selected tools and materials based on their specific needs. During their reflection, they shared insights from various learning aspects. Literacy, they understood the process of birds laying eggs in their nests. Science they explored how birds incubate their eggs and the transformation from eggs to chicks. Technology, they constructed the nest and coop using natural materials. Engineering, they utilized tools like string, wool thread, and other equipment to support the structure of the coop and nest, including the eggs. Art, they decorated the coop and nest to enhance their aesthetic appeal. Mathematics, they measured the number, size, and weight of the eggs.

Figure 3. The output of the team group Cicit Cuit
Source: Personal document of the informant (Nur Fatwikiningsih)

The team group "Cuit Cuit" has an idea to design bird nests on top of trees and on top of straw roofs of chicken coops by selecting tools and materials according to their needs. During their reflection, they shared that, from a literacy aspect, they learned about the different types of bird nests. From a science perspective, they gained knowledge about the process of bird reproduction, explaining why birds need to build nests. From a technology standpoint, they focused on constructing bird nests and chicken coops using natural materials. In terms of engineering, they built a bird nest made of straw with a strong structure for egg-laying, using raffia string, straw, twigs, thread, and other necessary modern tools. In the arts aspect, they created tree flowers where the bird nests were placed, using various colors, as well as different egg colors. In the mathematics aspect, they had counted the umber of birds, eggs, and flowers based on matching colors.

Figure 4. The output of the team group Cuit-Cuit
Source: Personal document of the informant (Nur Fatwikiningsih)

Through job competency training, both worker's performance and organizational's performance are enhanced (Mondy & Martocchio, 2016). The results of this study showed the STEAM based instructional training is effective in improving the pedagogical competence of early childhood education teachers. The pedagogical competence in STEAM for educators includes: 1) understand and apply teaching and learning techniques that support STEAM education; 2) apply collaborative learning methods in interrelated activities; 3) support independent learning in STEAM activities (Spyropoulou & Kameas, 2021). Sit (2022) support this by training for 2 (two) weeks related to the STEAM learning model is provided to improve teachers' knowledge of STEAM education, then through this training the teachers gained experience in selecting appropriate teaching methods, utilizing affordable learning media, and collaborating with subject matter experts but they required the availability of learning media and learning collaborators (Sit, 2022). Hence, the group assignments in this study were able to develop STEAM ideas by utilizing materials available in their surrounding environment and creatively designing STEAM lesson plans from both skill-building activities and main activities (tinkering) (Dolgopolovas, 2021).

The early childhood education teachers in this study understood and applied teaching and learning techniques that support STEAM education, aligned with the four stages of play for young children: explore, extend, engage, and evaluate (Tim GTK DIKDAS, 2021). They conducted practical simulations of activities starting from lesson plan preparation, explore, extend, engage, and evaluate stages. Similarly with results Yakman (2017) indicate that STEAM professional development can enhance teachers' interest in implementing STEAM approaches in the classroom then after the training 70% of the participants stated that they intended to begin implementing STEAM in their classrooms.

The another factors that challenges appeared during this training. First, different learning levels among trainee. Based result output statistical analysis showed the pre-test data normal, but the post-test data not normal, and data not homogeneous (Ng et al., 2022). This means the participants had different levels of understanding and ability to understand the training. Cause these differences from their previous experience, comfort with STEAM topics, or their teaching skills. Because of this, some trainee found it hard to keep up with speed their group or understand the materials fully. Second, Trainee difficulty applying theory to practice. Some of trainee hard to design lessons that included all five areas and still fit early childhood's learning needs. Third, lack of skills in using materials and tools.

Trainee accepted a lot of materials to use, include natural items and tools (Aimah et al., 2023). However, some trainee struggled to use these materials properly, especially for the engineering and technology parts. For example, building a strong bird nest with twigs and thread needed careful hand work and tool use. Not all of trainee had this experience, so it was a learning challenge for them. Fourth, coordinating within group dynamics. Some groups had different opinions or found it hard to manage their time (Abdurrahman & Ji, 2023). Others had problems dividing tasks fairly. Fifth, making STEAM ideas simple early childhood settings. Topics like how birds build nests or how to measure eggs had to be made fun and simple for early childhood (Apostolache, 2023). This took creativity, teaching skill, and a deep understanding of how early childhood learn. Sixth, limited experience with interdisciplinary planning. Trainee not accustomed to teaching one subject at a time (Afandi et al., 2023). The STEAM learning method asked them to mix different subjects together in one lesson. This was new and sometimes difficult. For example, they had to include art in science or use math during literacy time.

Conducting this research have limitations include design experiment did not minimise effect extraneous variable. Researcher need consideration how trainee are allocated to control and experimental group also determine best design experiment which suitable in this case. The use of a non-parametric test (Wilcoxon Signed-Rank Test) limits the generalizability of the findings. It is generally less powerful than parametric alternatives and more suitable for small samples. Therefore, the conclusions drawn from this research apply only to the specific context studied and cannot be generalized to a wider population. Aspect duration of training may have been insufficient for trainee to deeply understand training materials.

CONCLUSION

The STEAM-based instructional training had an impact to increase pedagogical competence of the early childhood education teachers. The trainee had better scores after the training. The median score increased by 36,5 points, which means there was a clear improvement in their teaching skills with the four stages from explore, extend, engage, and evaluate. They created lesson plans and solved real-world problems related to the topic. These projects helped them combine science, technology, engineering, art, and mathematic. Most participants were happy with the training. They gave positive feedback on the materials, structure, and teaching methods. Future research should use stronger design experiment, training with longer time duration, and study how the training works in real classrooms.

This study recommends strategic policies in human resource development. First, there is a need to develop a collaborative STEAM based instructional training. Second, the training targets should align with the needs of PAUD teachers, so that the training focuses not only on teachers' ability to remember and understand but also emphasizes their technical skills. Third, the development of a teacher's STEAM teaching module guidebook that provides real examples and step-by-step instructions is necessary to ensure teachers fully understand the implementation process and how to develop ideas about STEAM. Fourth, the curriculum update from the K-13 to the Merdeka Curriculum requires widespread, continuous socialization and follow-up evaluations to analyze training needs and ensure the goal training accurately.

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