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Conceptual PlayWorld as a STEAM Pedagogy for Enhancing Early Childhood Teachers' Science Teaching Competence

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Abstract

This study aimed to analyze the effectiveness of the Conceptual PlayWorld approach in improving early childhood education (ECE) teachers' competence in science teaching. This explanatory sequential mixed-methods study involved four early childhood teachers participating in a Conceptual PlayWorld professional development program. Using an explanatory sequential mixed-methods design, the research involved four ECE teachers as participants. Quantitative data were collected through a pre–posttest questionnaire consisting of 10 items measuring science teaching competence in play-based contexts. Qualitative data were obtained through participatory observations, semi-structured interviews, and teachers' reflective notes. The results demonstrate an increase in teachers' average competence scores from 2.85 (low category) to 4.10 (high category). A paired sample t-test confirmed a significant improvement ($t = 4.73$, $p < .05$). Qualitative findings revealed three major themes: (1) increased teacher confidence in responding to children's scientific questions; (2) enhanced ability to design imaginative play-based activities to connect scientific concepts; and (3) shifts in teachers' attitudes toward science teaching, viewing it as enjoyable and contextually meaningful. The study concludes that the Conceptual PlayWorld approach effectively strengthens conceptual understanding, pedagogical competence, and teachers' readiness to integrate play-based science activities in early childhood settings. The findings highlight the need for continuous professional development and the establishment of mentoring models that support play-based science inquiry for ECE teachers in Indonesia. Although the intervention focused primarily on science learning, the findings demonstrate the potential of Conceptual PlayWorld to support integrated STEAM pedagogies by connecting scientific inquiry with storytelling, creativity, problem-solving, and interdisciplinary thinking.

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INTRODUCTION

Science is a fundamental component of early childhood education because it stimulates curiosity, critical thinking, problem-solving skills, and early scientific literacy (Worth & Grollman, 2003; Gangal et al., 2026). During the golden age of development, young children naturally explore their environment, ask questions, and observe everyday phenomena (Bourha et al., 2026). These experiences form the foundation for developing scientific concepts and inquiry skills. When teachers are able to facilitate children's curiosity through meaningful science learning experiences (Kesner Baruch et al., 2025), children begin to engage in scientific practices, crosscutting concepts, and sensemaking that provide a foundation for future science learning (Raven & Wenner, 2023). Within contemporary educational perspectives, these scientific competencies also serve as an important foundation for integrated STEAM (Science, Technology, Engineering, Arts, and Mathematics) education (Mubarok et al., 2025), which emphasizes interdisciplinary problem-solving, creativity, and innovation from an early age.

However, both international and national literature consistently indicates that science learning in early childhood education continues to face persistent challenges. Chen et al. (2025) reported that many teachers struggle to integrate scientific concepts creatively because of limited pedagogical content knowledge, inadequate instructional resources, and insufficient examples of effective classroom practice. These challenges are evident not only in Western countries but also in Indonesia, where literacy and numeracy remain prominent areas of early childhood instruction, while the implementation of exploration-based science learning remains uneven and requires stronger pedagogical guidance (Nurhayati & Judijanto, 2026; Rusdiyani et al., 2025).

The contextual gap is particularly evident in Indonesia. Although the *Kurikulum Merdeka* promotes holistic, inquiry-based, project-oriented, and exploratory learning, many early childhood teachers report feeling unprepared to implement meaningful science activities because of limited professional development, insufficient understanding of basic scientific concepts, and minimal pedagogical mentoring. Consequently, science learning is frequently reduced to simple demonstrations rather than sustained conceptual exploration. At the classroom level, teachers often respond briefly to children's scientific questions—or avoid answering them altogether—because they lack confidence in explaining scientific phenomena. Questions such as *"Why does it rain?"*, *"Why does a shadow follow us?"*, and *"Why do objects fall downward?"* represent valuable opportunities for inquiry-based learning (Eshach, 2006), yet many teachers perceive them as difficult to explain in developmentally appropriate ways. This situation reflects a substantial contextual challenge in strengthening teachers' pedagogical content knowledge and confidence in facilitating science learning.

In addition to limited scientific understanding, another important barrier is teachers' low self-efficacy. Many early childhood teachers perceive science as a difficult subject that is more appropriate for primary education. Sowmya and Rani (2025) argue that low teacher confidence is one of the major obstacles to implementing inquiry-based science learning. This challenge is further exacerbated by the limited availability of contextual, low-cost, and play-based science activities that teachers can readily implement in everyday classroom practice.

To address these challenges, a pedagogical approach is needed that not only strengthens teachers' understanding of scientific concepts but also provides practical guidance for designing meaningful, enjoyable, and developmentally appropriate learning experiences. One promising approach is Conceptual PlayWorld (CPW), developed by Fleer (2009, 2021). CPW integrates imaginative storytelling, role play, dialogue, and guided exploration to support children's conceptual understanding while positioning teachers as active facilitators of inquiry. Grounded in Vygotsky's (1978) sociocultural theory and the concept of the Zone of Proximal Development (ZPD), CPW emphasizes social interaction, scaffolding, and imaginative play as mechanisms for promoting higher-order cognitive development.

Previous studies have demonstrated that Conceptual PlayWorld enhances children's conceptual understanding, inquiry skills, higher-order thinking, and meaningful teacher–child interactions (Fleer, 2009, 2021). Nevertheless, most existing research has primarily focused on children's learning outcomes and the pedagogical characteristics of Conceptual PlayWorld. Empirical evidence examining how this approach strengthens teachers' professional competence, particularly their competence in facilitating science learning, responding to children's scientific questions, and designing inquiry-oriented learning activities, remains limited. Moreover, research investigating the implementation of Conceptual PlayWorld within the Indonesian early childhood context is still scarce. Existing Indonesian studies have largely emphasized media development, STEM-based project activities, or numeracy instruction, while relatively little attention has been given to imaginative, inquiry-based science pedagogy for teachers.

Furthermore, although Conceptual PlayWorld has been widely discussed within early childhood science education, little attention has been paid to its contribution to integrated STEAM education. Contemporary STEAM education emphasizes interdisciplinary learning by integrating scientific inquiry with technological thinking, engineering design, mathematical reasoning, creativity, and the arts. The imaginative, story-based nature of Conceptual PlayWorld offers considerable potential to support these interdisciplinary competencies by encouraging children and teachers to solve authentic problems collaboratively through play, storytelling, exploration, and creative design. However, empirical evidence demonstrating how Conceptual PlayWorld contributes to integrated STEAM pedagogy remains limited.

Therefore, this study seeks to address both the contextual challenges faced by Indonesian early childhood teachers and the empirical gaps in existing Conceptual PlayWorld research. Specifically, this study investigates whether the Conceptual PlayWorld approach enhances teachers' competence in science teaching while exploring its potential to support interdisciplinary STEAM pedagogy through play-based learning.

Accordingly, this study addresses the following research questions:

1. Does the Conceptual PlayWorld approach improve early childhood teachers' competence in science teaching?
2. How do teachers perceive and experience the implementation of the Conceptual PlayWorld approach?
3. How do teachers' instructional practices in responding to children's scientific questions change after participating in the Conceptual PlayWorld training?

By addressing these questions, this study contributes to the literature on both early childhood science education and integrated STEAM education. The findings are expected to provide empirical

evidence for the design of teacher professional development programs that strengthen inquiry-oriented, interdisciplinary, and play-based pedagogical practices for early childhood education in Indonesia.

METHOD

Research Design

This study employed an explanatory sequential mixed-methods design, consisting of two phases that began with the collection and analysis of quantitative data, followed by qualitative data collection to provide a deeper explanation of the quantitative findings (Creswell & Plano Clark, 2018). This design was selected because improvements in teachers' competence cannot be fully understood through numerical scores alone but should also be interpreted through teachers' experiences, perceptions, and observable pedagogical practices. The integration of quantitative and qualitative findings enabled a comprehensive understanding of how the Conceptual PlayWorld (CPW) approach influenced teachers' professional learning and instructional practices.

Participants

The participants consisted of four early childhood education (ECE) teachers from one district in Bandar Lampung City, Indonesia. Participants were selected using purposive sampling based on the following criteria:

1. Having at least one year of teaching experience in early childhood education.
2. Actively implementing play-based learning.
3. Willing to participate throughout all phases of the study, including the pre-test, training sessions, classroom implementation, observations, interviews, and reflective activities.

Although the sample size was limited (N = 4), this study was designed as an exploratory pilot intervention to obtain an in-depth understanding of teachers' professional learning during the implementation of Conceptual PlayWorld. Within an explanatory sequential mixed-methods design, qualitative depth and contextual understanding are prioritized over statistical generalization (Creswell & Plano Clark, 2018). Therefore, the small sample allowed intensive observation, continuous mentoring, repeated classroom visits, and rich qualitative data collection, providing valuable insights for future large-scale studies.

Research Instruments

Science Teaching Competence Questionnaire

The questionnaire was developed based on early childhood science literacy (Worth & Grollman, 2003), pedagogical content knowledge (Shulman, 1987), and the Conceptual PlayWorld framework (Fleer, 2009, 2021). It consisted of ten Likert-scale items (1 = very low to 5 = very high) covering three dimensions: understanding of basic science concepts (4 items), pedagogical self-efficacy in science teaching (3 items), and ability to design play-based science learning activities (3 items),
The instrument was reviewed by three experts specializing in educational psychology, early childhood education, and science education. Content validity reached a Content Validity Index (CVI) of 0.83. Construct validity was assessed through Corrected Item-Total Correlation using pilot data from twelve ECE teachers, producing coefficients ranging from 0.41 to 0.72. Internal consistency reliability was satisfactory (Cronbach's α = .87).

Classroom Observation

Structured classroom observations documented teachers' instructional behaviors, including responses to children's scientific questions, use of inquiry strategies, implementation of Conceptual PlayWorld elements, and classroom interactions. Two researchers independently conducted observations to improve trustworthiness through investigator triangulation.

Semi-Structured Interviews

Post-intervention interviews explored teachers' experiences, perceived benefits, implementation challenges, and changes in instructional beliefs following participation in the Conceptual PlayWorld program.

Reflective Journals

Teachers maintained reflective journals throughout the intervention to document changes in their understanding, confidence, instructional decision-making, and classroom experiences.

Intervention Procedure

The Conceptual PlayWorld professional development program was implemented over five consecutive weeks.

Week 1 – Introduction

Teachers participated in an introductory workshop discussing early childhood science learning, inquiry pedagogy, and the theoretical foundations of Conceptual PlayWorld.

Week 2 – Modelling and Simulation

Researchers demonstrated several Conceptual PlayWorld activities, including storytelling, role play, scientific dialogue, and inquiry-based exploration. Teachers participated in guided simulations.

Week 3 – Collaborative Lesson Planning

Teachers collaboratively designed Conceptual PlayWorld lesson scenarios by integrating scientific concepts, imaginative narratives, classroom activities, and play-based investigations appropriate for young children.

Week 4 – Classroom Implementation and Mentoring

Teachers implemented their lesson plans in their own classrooms. During implementation, researchers provided classroom mentoring, observation, and immediate pedagogical feedback to support instructional improvement.

Week 5 – Reflection and Evaluation

Teachers completed the post-test questionnaire, participated in semi-structured interviews, submitted reflective journals, and discussed their implementation experiences during a group reflection session.

Data Analysis

Quantitative Analysis

Quantitative data were analyzed using descriptive and inferential statistics. Descriptive statistics included: mean, standard deviation, minimum score, maximum score, and mean difference between pre-test and post-test

Normality was examined using the Shapiro–Wilk test before conducting a paired-sample t-test. To strengthen interpretation of the intervention effect, the analysis also included: 95% confidence intervals for the mean difference; and Cohen's d effect size, providing information regarding the magnitude of the intervention beyond statistical significance. A significance level of $p < .05$ was adopted for all statistical analyses.

Qualitative Analysis

Qualitative data from classroom observations, interviews, and reflective journals were analyzed using Braun and Clarke's (2006) six-step thematic analysis:

1. Familiarization with the data
2. Initial coding
3. Theme generation
4. Theme review
5. Theme definition and refinement
6. Report production

Trustworthiness was strengthened through source triangulation, investigator triangulation, and member checking.

Mixed-Methods Integration

Following separate quantitative and qualitative analyses, findings were integrated using both a side-by-side comparison and a joint display, enabling direct comparison between statistical results and qualitative evidence.

The joint display facilitated interpretation of how improvements observed quantitatively were supported and explained by teachers' classroom experiences, reflective journals, and interview findings, thereby providing meta-inferences regarding the effectiveness of the Conceptual PlayWorld intervention.

RESULTS AND DISCUSSION

Quantitative Result

Table 1. Result of Pre-test and Post-test Scores

Subject	Pre-test	Post-test
Subject 1	2.7	4.2
Subject 2	2.9	4.0
Subject 3	3.0	4.1
Subject 4	2.8	4.1

Table 1 presents the individual pre-test and post-test scores of the four participating teachers. All teachers showed notable improvement after the implementation of the Conceptual PlayWorld approach. Pre-test scores ranged from 2.7 to 3.0, while post-test scores increased to between 4.0 and 4.2, indicating consistent improvement across all subjects.

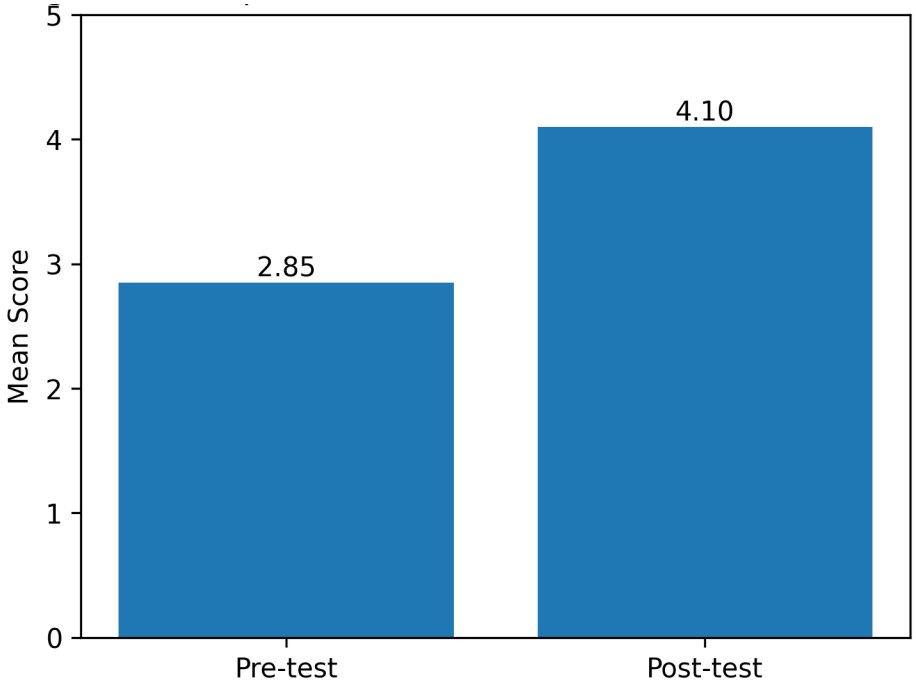

Figure 1. Comparison of Mean Pre-test and Post-test score.

The figure visually illustrates the increase in teachers' science teaching competence following the Conceptual PlayWorld intervention. The average competence score increased from 2.85 before the intervention to 4.10 after the intervention, indicating substantial improvement across participants.

Table 2.Descriptive Statistics of Pre-test and Post-test Scores

Variable	Mean	SD	Minimum	Maximum	Category
Pre-test	2.85	0.13	2.70	3.00	Low
Pos-test	4.10	0.10	4.00	4.20	High

Table 2 presents descriptive statistics of teachers' competence before and after the intervention. The average pre-test score was 2.85 (SD = 0.13), ranging from 2.70 to 3.00, indicating relatively low competence prior to the intervention. Following the Conceptual PlayWorld training, the average score increased to 4.10 (SD = 0.10), with scores ranging from 4.00 to 4.20. The relatively small standard deviations in both measurements indicate consistent performance among participants. Overall, these descriptive findings suggest substantial improvement in teachers' science teaching competence after participation in the Conceptual PlayWorld program.

Table 3. Test Normality of Saphiro Wilk

Variable	W	p-value	Description
Pre-test	0.965	0.78	Normal
Pos-test	0.945	0.65	Normal

The Shapiro–Wilk test was used to examine whether the pre-test and post-test scores were normally distributed. The results showed that both the pre-test (W = 0.965, p = 0.78) and post-test (W

= 0.945, p = 0.65) scores met the assumption of normality (p > .05). This indicates that the data were suitable for further analysis using a paired sample t-test.

Table 4. Paired T-test

Variable	Mean Difference	*t* (*df* = 3)	*p*	95% CI	Cohen's d
Pre-test → Post-test	1.25	13.06	0.001	[0.95, 1.55]	6.53

A paired-sample *t*-test was conducted to determine whether teachers' science teaching competence significantly improved following the Conceptual PlayWorld intervention. The analysis revealed a statistically significant increase in post-test scores compared with pre-test scores, $t(3) = 13.06$, $p = .001$. The mean improvement was 1.25 points (95% CI [0.95, 1.55]), indicating that teachers consistently achieved higher competence scores after the intervention. Furthermore, the effect size was extremely large (*Cohen's d* = 6.53), suggesting that the Conceptual PlayWorld intervention had a substantial practical impact on teachers' science teaching competence. Although these findings should be interpreted cautiously because of the small sample size, they provide strong preliminary evidence supporting the effectiveness of the intervention in this exploratory pilot study.

Qualitative Findings

Qualitative data were analyzed using Braun and Clarke's (2006) thematic analysis. Observations, interviews, and teacher reflection journals yielded three major themes that illustrate changes in teachers' competence and classroom practice after participating in the Conceptual PlayWorld training. The themes are presented as follows.

Theme 1: Increased Teacher Confidence in Explaining Scientific Concepts

One of the most prominent changes was the improvement in teachers' confidence when responding to children's critical questions and explaining simple scientific phenomena. Prior to the intervention, teachers tended to avoid such questions and provided only brief or normative responses. After the training, teachers showed greater initiative in using hands-on activities to explain concepts more effectively.

Subthemes:

1. Ability to link children's questions with simple experiments
2. Transformation from verbal explanations to exploratory experiences

Data Evidence:

Teacher I stated during the interview: "Usually when a child asks, 'Why does this sink?', I am unsure how to answer. Now I immediately invite the children to test different objects in water. They understand more quickly, and I feel more confident."

Teacher III added: "I feel braver when explaining. With just a small experiment, children can see what happens by themselves."

These findings indicate an increase in teachers' pedagogical self-efficacy. When teachers feel competent in instructional strategies, they are more prepared to respond constructively to children's inquiries. The Conceptual PlayWorld approach enables teachers to treat children's questions as entry points for scientific interaction through concrete experiences.

Theme 2: Integration of Storytelling and Imagination as Tools for Teaching Science
Teachers began to integrate imaginative storytelling into their science instruction. Stories were not used merely for entertainment but served as conceptual structures that support children's understanding of scientific phenomena.
Subthemes:

1. Use of narrative flow to explain scientific phenomena
2. Utilization of imaginative characters to facilitate scientific dialogue

Data Evidence:
Teacher ii wrote in her reflection journal: "The children were very engaged when I used the 'Magic Ball' story. Through that story, I could introduce the concept of bouncing without them feeling like they were learning science."
Teacher IV reinforced this point: "Through stories, they ask more questions. The characters help me explain concepts like light or pushing forces."

The integration of imagination enriches the context of science learning and aligns closely with the principles of the Conceptual PlayWorld, which connects abstract concepts to children's play worlds. This also reflects a shift from one-way demonstration to interactive, narrative-based dialogue.

Theme 3: Transformation of Teachers' Attitudes Toward Science Learning
Before the training, teachers perceived science as a difficult subject unsuitable for early childhood education. After the intervention, they developed the view that science can be taught in simple, enjoyable, and developmentally appropriate ways.
Subthemes:

1. Changing perceptions that science does not need to be complex
2. Viewing science as a meaningful play-based activity

Table 5. Joint Display of Quantitative and Qualitative Findings

Quantitative Findings	Qualitative Evidence	Integrated Interpretation
Significant increase in post-test scores	Teachers reported greater confidence in answering children's scientific questions	Quantitative improvement reflects enhanced pedagogical self-efficacy.
Higher competence in lesson planning	Observation showed teachers designed more inquiry-based play activities	CPW strengthened teachers' pedagogical competence.
Improved science teaching competence	Reflection journals indicated more positive attitudes toward science	Professional learning extended beyond knowledge acquisition to changes in beliefs and practices.
Consistent improvement across participants	Interviews revealed increased willingness to facilitate children's inquiry	Qualitative findings explain the consistency observed in quantitative results.

The joint display demonstrates convergence between quantitative and qualitative findings. Improvements identified through statistical analysis were consistently supported by teachers'

interviews, classroom observations, and reflective journals, providing stronger evidence regarding the effectiveness of the Conceptual PlayWorld intervention.

Data Evidence:
Teacher I expressed: "At first, I thought science was only for primary school. Now I see that it can be made very simple, and the children really enjoy it."
Teacher III added during the member-checking session: "I realized that what matters is not the scientific terms, but giving children the chance to try and see for themselves."

This change demonstrates a shift in teachers' pedagogical mindset, an essential transformation because teacher attitudes significantly influence the quality of science learning (Chen et al., 2025). When teachers perceive science as enjoyable and accessible, the likelihood of implementing exploratory, play-based science activities increases substantially.

The findings of this study indicate that the Conceptual PlayWorld (CPW) approach is effective in enhancing early childhood teachers' competence in science teaching. Quantitative findings demonstrated a significant improvement in teachers' post-test scores following the intervention, while qualitative evidence from interviews, classroom observations, and reflective journals further explained how this improvement occurred. Teachers reported greater confidence in responding to children's scientific questions, designing inquiry-oriented activities, and integrating imaginative storytelling into classroom instruction. The convergence of quantitative and qualitative findings suggests that Conceptual PlayWorld contributes not only to measurable improvements in teacher competence but also to meaningful changes in pedagogical beliefs and instructional practices.

The improvement in teachers' competence supports Fleer's (2009, 2021) proposition that imagination and narrative play worlds function as mediating tools through which both teachers and children construct conceptual understanding. Rather than presenting scientific concepts through formal instruction, Conceptual PlayWorld creates meaningful learning situations where scientific inquiry emerges naturally through imaginative play. This pedagogical process enables teachers to facilitate children's exploration while simultaneously strengthening their own pedagogical content knowledge and instructional confidence.

An important finding of this study is the significant increase in teachers' science teaching self-efficacy. According to Bandura (1997), self-efficacy strongly influences individuals' willingness to undertake challenging tasks and persist when difficulties arise. Likewise, Tschannen-Moran and Hoy (2001) argue that teachers with higher instructional efficacy are more likely to employ innovative teaching strategies, provide richer pedagogical interactions, and respond more effectively to students' learning needs. Prior to the intervention, participants frequently described science as a difficult subject that was more appropriate for primary education. Following the CPW training, however, teachers became increasingly confident in explaining scientific concepts such as force, motion, floating and sinking, gravity, and light through simple experiments and guided exploration. These findings are consistent with Appleton (2007) and Yoon et al. (2026), who reported that inquiry-based learning helps teachers overcome limitations in science content knowledge by emphasizing investigation rather than direct explanation.

The qualitative findings further revealed that teachers increasingly viewed children's spontaneous questions as opportunities for scientific inquiry rather than instructional challenges. Eshach (2006) argues that children's curiosity provides the foundation for developing scientific literacy because authentic questions stimulate observation, prediction, experimentation, and

explanation. In the present study, teachers shifted from providing brief, factual answers toward encouraging children to investigate scientific phenomena through hands-on exploration. This transformation reflects the development of inquiry-oriented pedagogy and addresses a documented need in early childhood science education. Preschool teachers often report only moderate confidence in teaching science and limited knowledge of the full inquiry process, which can restrict inquiry activities to observation and questioning (Hollingsworth & Vandermaas-Peeler, 2017).

Another important contribution of this study is the integration of imaginative storytelling into science instruction. Teachers reported that stories enabled children to engage more actively with scientific ideas because abstract concepts became embedded within meaningful play contexts. The "Magic Ball Adventure," for example, provided opportunities for children to investigate bouncing, force, and gravity while remaining immersed in an imaginative narrative. This finding is consistent with Vygotsky's (1978) sociocultural theory, which emphasizes symbolic play as a mechanism for cognitive development, and with Norris et al. (2005), who demonstrated that narrative contexts enhance children's conceptual understanding by connecting scientific ideas with familiar experiences. Similarly, Pedaste et al. (2015) emphasize that contextual scaffolding supports meaningful inquiry by linking children's prior knowledge with new scientific concepts. Furthermore, Pramling Samuelsson and Fleer (2008) argue that narrative structures help teachers organize scientific interactions in ways that sustain children's engagement and conceptual development.

Although the intervention primarily focused on improving teachers' competence in science teaching, the findings also demonstrate the broader pedagogical potential of Conceptual PlayWorld as an integrated STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. Contemporary STEAM education emphasizes interdisciplinary learning experiences that integrate scientific inquiry with creativity, mathematical reasoning, engineering design, and communication rather than treating each discipline separately (Yakman & Lee, 2012). Within the Conceptual PlayWorld activities, teachers integrated scientific concepts through storytelling, collaborative investigation, and imaginative problem-solving. Children compared object movements, estimated distances, predicted outcomes, discussed observations, and explored alternative solutions presented within story-based scenarios. These learning experiences naturally incorporated mathematical reasoning, artistic expression, communication skills, and engineering-like thinking while maintaining scientific inquiry as the central learning process.

The findings also suggest that Conceptual PlayWorld has considerable potential to foster teachers' interdisciplinary pedagogical competence. Storytelling encouraged creativity and communication, while inquiry-based investigations promoted critical thinking and collaborative problem solving. Narrative contexts also created opportunities for simple engineering design challenges in which children constructed objects, tested alternative ideas, modified materials, and evaluated solutions. Although technology integration was not explicitly implemented during this intervention, the flexible nature of Conceptual PlayWorld provides opportunities to incorporate age-appropriate digital resources, multimedia storytelling, or digital observation tools to enrich future STEAM learning experiences. Consequently, the present study extends previous Conceptual PlayWorld research by demonstrating its contribution not only to science pedagogy but also to the development of integrated STEAM competencies among early childhood teachers.

These findings are particularly relevant within the Indonesian context, where early childhood teachers frequently report limited confidence and insufficient preparation for teaching science. Previous studies (Nurhayati & Judijanto, 2026; Rusdiyani et al., 2025) indicate that science learning

often receives less attention than literacy and numeracy because teachers lack appropriate pedagogical models and professional support. The present findings suggest that Conceptual PlayWorld offers several practical advantages for Indonesian early childhood education. First, the approach relies primarily on storytelling, imagination, and readily available classroom materials, making it feasible for implementation in resource-limited settings. Second, its play-based structure aligns well with children's developmental characteristics and the pedagogical principles of the *Kurikulum Merdeka*. Third, the approach successfully increased teachers' confidence and motivation by providing concrete examples of inquiry-based science instruction that were perceived as simple, enjoyable, and achievable. These findings support national studies emphasizing the importance of structured play-based pedagogy for improving early childhood science education (Junaedi et al., 2023).

Another important finding concerns the role of mentoring throughout the intervention. Teachers consistently reported that classroom demonstrations, collaborative lesson planning, guided practice, and immediate feedback were among the most valuable components of the professional development program. These findings support Santangelo and Tomlinson's (2012) assertion that teacher professional development is most effective when it combines theoretical learning with sustained mentoring, classroom practice, and reflective dialogue. In the present study, mentoring functioned as pedagogical scaffolding that enabled teachers to translate theoretical principles of Conceptual PlayWorld into authentic classroom practice while gradually developing confidence in facilitating children's scientific inquiry.

Theoretically, this study contributes to the growing body of literature on Conceptual PlayWorld by extending its application from children's conceptual learning to teachers' professional competence within an Indonesian context. While previous studies have primarily focused on children's learning outcomes, the present findings provide empirical evidence that Conceptual PlayWorld can also strengthen teachers' pedagogical knowledge, instructional confidence, and interdisciplinary teaching competence. Furthermore, this study demonstrates that the approach has considerable potential to support integrated STEAM pedagogy through inquiry-oriented, imaginative, and play-based learning experiences.

From a practical perspective, the findings have important implications for teacher professional development and educational policy. Conceptual PlayWorld may serve as a sustainable framework for in-service teacher education because it integrates theoretical understanding, modelling, collaborative lesson planning, classroom implementation, mentoring, and reflective practice. Educational authorities could incorporate Conceptual PlayWorld into continuous professional development programs to support the implementation of *Kurikulum Merdeka* while strengthening teachers' interdisciplinary STEAM competencies. Likewise, universities responsible for pre-service teacher education may integrate Conceptual PlayWorld into early childhood teacher preparation curricula to develop future teachers who are capable of implementing inquiry-oriented, play-based, and integrated STEAM learning. Because the approach is developmentally appropriate, low-cost, and adaptable to diverse educational contexts, it represents a promising strategy for improving the quality of early childhood education in Indonesia and other developing countries.

CONCLUSION

This study concludes that the Conceptual PlayWorld (CPW) approach is effective in enhancing early childhood education teachers' competence in science teaching. Quantitative findings demonstrated

significant improvements in teachers' post-test scores, while qualitative evidence revealed meaningful changes in teachers' confidence, instructional creativity, and classroom practices. Improvements were evident across three key dimensions: understanding of basic scientific concepts, pedagogical self-efficacy, and the ability to design inquiry-oriented, play-based learning activities. Teachers also became more confident in responding to children's scientific questions and facilitating exploratory learning experiences through storytelling, experimentation, and guided inquiry.

Beyond strengthening science teaching competence, the findings indicate that Conceptual PlayWorld has considerable potential to support integrated STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. By combining imaginative storytelling, collaborative inquiry, creative problem-solving, and play-based exploration, the approach encourages interdisciplinary learning experiences that align with contemporary STEAM pedagogy. Consequently, this study extends previous Conceptual PlayWorld research by demonstrating its contribution not only to early childhood science education but also to the development of broader interdisciplinary teaching competencies required for effective STEAM instruction.

Despite these promising findings, several limitations should be acknowledged. First, the study involved only four participants, limiting the generalizability of the findings. As an exploratory pilot study, however, the primary objective was to obtain an in-depth understanding of teachers' professional learning during the implementation of Conceptual PlayWorld rather than to produce statistically generalizable results. Second, the intervention was conducted over a relatively short period, preventing examination of the long-term sustainability of changes in teachers' instructional practices. Third, the study focused primarily on teachers' competence and did not directly evaluate children's science learning outcomes or broader STEAM competencies.

Future research should employ larger and more diverse samples involving teachers from different educational contexts to strengthen the generalizability of the findings. Experimental or quasi-experimental designs incorporating comparison groups would provide stronger evidence regarding the effectiveness of Conceptual PlayWorld. Longitudinal studies are also recommended to examine the sustainability of teachers' pedagogical development over time. Furthermore, future investigations should evaluate children's learning outcomes, including scientific literacy, inquiry skills, creativity, problem-solving, and interdisciplinary STEAM competencies, while exploring how technology and engineering design activities can be more systematically integrated into the Conceptual PlayWorld framework.

The findings have important implications for teacher professional development and educational policy. Conceptual PlayWorld provides a practical and developmentally appropriate framework for strengthening teachers' pedagogical competence through modelling, collaborative lesson planning, classroom implementation, mentoring, and reflective practice. Because the approach relies primarily on storytelling, imagination, and readily available learning materials, it is feasible for implementation in resource-limited early childhood settings. Educational authorities may consider incorporating Conceptual PlayWorld into continuous professional development initiatives to support the implementation of *Kurikulum Merdeka* and promote integrated STEAM pedagogy. Likewise, teacher education institutions may adopt this approach within pre-service preparation programs to equip future teachers with inquiry-oriented, interdisciplinary, and play-based instructional competencies. Overall, this study provides empirical evidence that Conceptual PlayWorld is a promising pedagogical and professional development approach for early childhood education. By strengthening teachers' competence in science teaching while supporting interdisciplinary STEAM learning through imaginative and inquiry-based experiences, the

approach offers valuable contributions to improving the quality of early childhood education in Indonesia and other developing countries.

STATEMENTS AND DECLARATIONS

Competing Interests. The authors declare no competing interests.

Author Contributions. CW: Conceptualization, project administration, and writing the original draft. CW and RHA contributed equally to the methodology, program implementation, data collection, data curation, formal analysis, interpretation of the findings, visualization, and review and editing of the manuscript. Both authors reviewed and approved the final version of the manuscript.

Ethics Approval. Ethical approval for this study was granted by UIN Raden Intan Lampung.

Informed Consent to Participate. Informed consent was obtained from all participants before data collection. Participation was voluntary, and the participants were informed about the purpose of the study, the data collection procedures, and their right to withdraw.

Consent for Publication. Not applicable. No identifiable personal information is reported in this article, and all participant quotations are presented anonymously.

Data Availability. The anonymized data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to ethical and privacy considerations.

Use of Artificial Intelligence Tools. Grammarly was used to support grammar and language correction. ChatGPT (OpenAI) was used to support language refinement and the translation of selected participant quotations from Indonesian into English. The authors independently checked all translations, citations, references, and final wording against the original data and sources. The authors take full responsibility for the content of the manuscript.

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