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# Learn and Play Activities to Support Early Childhood Teacher's Understanding of Electrical Energy Concepts

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**ABSTRACT**

**Purpose:** This study investigates early childhood education (ECE) teachers' understanding of fundamental electrical energy concepts, including sources of electrical energy, energy conversion, and simple electrical circuits, and examines how Learn and Play–based activities can support their pedagogical preparation. **Methods:** A mixed-methods design was used, combining quantitative pre- and post-tests with qualitative phenomenological interviews. Twenty ECE teachers from six institutions in Madiun City and Madiun Regency participated. The intervention consisted of three sequential phases: basic concept training, theoretical–practical mentoring, and pedagogical assistance. Data were collected through tests, observations, lesson plan assessments, and interviews. **Findings:** On average, teachers' test scores increased from 42.3% (pre-test) to 78.6% (post-test) after the first training phase. During mentoring, 16 of 20 teachers successfully produced lesson plans that met early childhood science criteria, and classroom observations showed improved accuracy in explaining simple electrical circuits. Teachers reported greater confidence in integrating electrical concepts into Learn and Play activities, particularly in designing exploratory experiments connected to children's daily experiences. **Research implications:** The structured mentoring model used in this study may be useful for supporting teachers' scientific literacy, particularly on simple electrical topics. However, further research with larger groups and controlled comparisons is needed. **Originality:** Rather than claiming novelty, this study contributes applied evidence on how Learn and Play activities can enhance teachers' understanding of basic electrical concepts within an early childhood education context.



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## INTRODUCTION

Science learning in early childhood education (ECE) is widely recognized as a critical foundation for developing children's curiosity, reasoning skills, and early scientific literacy (Cain, 2019; Darling-Hammond et al., 2020). However, in practice, current science instruction at the preschool level often remains limited in depth. Furthermore, science instruction remains heavily reliant on individual teacher understanding and experience. This issue becomes more pronounced when addressing abstract scientific concepts, such as electrical energy, which cannot be directly observed by children. As a result, early science learning may fail to establish meaningful conceptual understanding and instead risks reinforcing incomplete or inaccurate ideas from an early stage (Andersson & Gullberg, 2014; Fandakova & Gruber, 2021; Jirout & Zimmerman, 2015; Herianto & Wilujeng, 2020).

Previous studies have shown that effective science learning in early childhood is strongly influenced by teachers' content knowledge and pedagogical competence. Research indicates that young children learn science more effectively when concepts are connected to their everyday experiences and supported through active exploration (Cabe Trundle & Saçkes, 2021; Campbell & Chittleborough, 2014; Piasta et al., 2014). However, the literature also highlights persistent misconceptions related to electricity, not only among students but also among teachers. For instance, misunderstandings about electric current, energy sources, and circuit functioning are commonly reported and tend to persist without targeted intervention (Allen, 2015; Fragkiadaki & (Olaogun et al., 2023; Ravanis, 2015; Sackes, 2015; Solomonidou & Kakana, 2000). At the same time, studies on teacher readiness emphasize that many early childhood educators have limited pedagogical content knowledge (PCK) in science, particularly in physics-related topics such as electricity, which affects their ability to design meaningful learning experiences (Berry et al., 2015; Gess-Newsome et al., 2019; Leuchter et al., 2020; Schmitt et al., 2023).

Despite these findings, there is still limited empirical research that explicitly integrates three key aspects: (1) strengthening teachers' conceptual understanding of electrical energy, (2) addressing misconceptions through structured support, and (3) developing teachers' pedagogical ability to translate abstract concepts into developmentally appropriate learning activities. In particular, few studies have examined how teachers' personal experiences with everyday electrical phenomena can be systematically incorporated into professional development programs. This indicates a clear research gap in the connection among conceptual literacy, experiential knowledge, and pedagogical practice in early childhood science education.

The Learn and Play approach provides a relevant and theoretically grounded framework to address this gap. Play-based learning has been widely recognized as a core principle in early childhood education, allowing children to construct knowledge through active, meaningful, and context-based experiences (Vygotsky et al., 2016; Worth, 2010). When combined with guided instruction, this approach can also support teachers in transforming abstract scientific concepts into concrete learning activities. Furthermore, integrating teachers' personal experiences with structured exploration aligns with engaged learning principles, which emphasize active participation, collaboration, and knowledge construction (Hung et al., 2006). Therefore, Learn and Play serves as a logical intervention to bridge the gap between conceptual understanding and pedagogical implementation in teaching electricity.

Based on this rationale, this study aims to examine how a structured training and mentoring program based on Learn and Play activities supports early childhood education teachers' understanding of basic electrical concepts and their ability to design appropriate learning activities. Specifically, this study addresses the following research questions: (1) How do teachers understand fundamental electrical concepts after participating in the intervention? and (2) How do teachers design Learn and Play–based learning activities that align with early childhood science learning principles?.

# METHOD

## Research Design

This study employed a mixed-methods intervention design with a sequential explanatory approach, in which quantitative data were collected and analyzed in the initial phases, followed by qualitative data to explain and deepen the findings. The quantitative component focused on measuring changes in teachers' conceptual understanding across phases, while the qualitative component explored teachers' experiences, challenges, and pedagogical development during the intervention. Integration of data occurred at two points: (1) during phase-by-phase interpretation, where quantitative results informed the focus of subsequent mentoring, and (2) at the final stage, where qualitative findings were used to explain observed changes in test scores and teaching practices.

## Research Context and Participants

The study was conducted in six early childhood education institutions in Madiun City and Madiun Regency, Indonesia. Participants were selected purposively based on teaching experience and willingness to participate in the full intervention program. A total of 20 teachers participated in all phases of the study.

**Table 1.** Participant Characteristics

| Code | Institution | Teaching Experience | Educational Background |
|---|---|---|---|
| T1–T3 | School A | 5–10 years | Bachelor (ECE) |
| T4–T6 | School B | 5–12 years | Bachelor (ECE) |
| T7–T10 | School C | 6–15 years | Bachelor (ECE) |
| T11–T13 | School D | 5–10 years | Bachelor (ECE) |
| T14–T17 | School E | 7–15 years | Bachelor (ECE) |
| T18–T20 | School F | 5–12 years | Bachelor (ECE) |

## Research Procedure

The intervention consisted of three integrated phases:

a. Phase 1: Basic Training (Pre-test – Training – Post-test 1)

Teachers completed a pre-test assessing their initial understanding of basic electrical concepts. This was followed by training sessions covering energy sources, energy conversion, and simple circuits. At the end of this phase, teachers completed Post-test 1.

b. Phase 2: Follow-up Mentoring (Conceptual and Planning Support)

Teachers received small-group mentoring focusing on conceptual clarification, practical activities (e.g., simple circuits), and development of lesson plans (RPP). At the end of this phase, teachers completed Post-test 2 and submitted lesson plans.

c. Phase 3: Pedagogical Mentoring and Classroom Implementation

Teachers conducted teaching simulations followed by real classroom implementation. This phase included teaching practice, observation of classroom implementation, evaluation of pedagogical performance, and student engagement.

**Instruments**

1. Conceptual Understanding Test
    a. Format: 8 open-ended items
    b. Example item: *"Explain why a light bulb turns on in a simple circuit."*
    c. Scoring rubric (1–4 scale):
        1) 1 = incorrect/no understanding
        2) 2 = partial understanding with misconceptions
        3) 3 = mostly correct with minor errors
        4) 4 = scientifically accurate and complete
    d. Passing criterion: minimum average score ≥ 3
    e. Validity & reliability:
        1) Content validity established through expert review (2 science education experts)
        2) Internal consistency checked using inter-rater agreement (two scorers; agreement >85%)
2. Lesson Plan Assessment Rubric
    a. Aspects assessed:
        1) Concept accuracy
        2) Alignment with ECE principles
        3) Integration of Learn and Play
        4) Feasibility of activities
    b. Scale: 1–4 per criterion
    c. Passing criterion: average score ≥ 3
3. Observation Sheet (Pedagogical Competence)
    a. Indicators:
        1) Clarity of explanation
        2) Use of concrete examples
        3) Student engagement
        4) Integration of practice
    b. Scale:
        1) Able (3)
        2) Adequately able (2)
        3) Less able (1)
4. Interview Guide
    Semi-structured interviews explored:
    a. Teachers' experiences with electricity
    b. Perceived difficulties
    c. Changes in understanding
    d. Reflections on teaching practice

**Data Analysis**

1. Quantitative Analysis
    Quantitative data from pre-test and post-tests were analyzed using descriptive statistics, including:
    a. Mean scores
    b. Percentage distribution of score categories
    c. Comparison across phases
    Score changes were interpreted as indicative trends of improvement, without applying inferential statistical tests.

2. Qualitative Analysis
    Qualitative data from interviews and observations were analyzed using thematic analysis:
    a. Data familiarization
    b. Initial coding
    c. Category development
    d. Theme identification

    To enhance trustworthiness:
    a. Triangulation was conducted across interviews, observations, and test results
    b. Member checking was applied to confirm participants' responses

3. Ethical Considerations

All participants provided informed consent. Schools and participants were anonymized using codes to ensure confidentiality.

# RESULTS

***Phase 1: Basic Training (Pre-test and Post-test 1)***

Quantitative Results Table 2 presents the distribution of teachers' scores in the pre-test and Post-test 1.

**Table 2.** Distribution of Scores (Pre-test vs Post-test 1)

| Score | Pre-test (f) | Post-test 1 (f) |
|---|---|---|
| 1 | 10 | 0 |
| 2 | 8 | 6 |
| 3 | 2 | 4 |
| 4 | 0 | 10 |
| **Total** | **20** | **20** |

Descriptive statistics indicate an increase in average scores.

**Table 3.** Descriptive Statistics

| Test | Mean | SD |
|---|---|---|
| Pre-test | 1.60 | 0.68 |
| Post-test 1 | 3.20 | 0.89 |

These results show a shift in score distribution from lower categories (scores 1–2) to higher categories (scores 3–4).

Qualitative Findings (Phase 1)

Three main themes emerged from interviews and observations:

1. Limited Initial Conceptual Understanding
   Most teachers described electricity in general terms without scientific explanation.
   "The lights come on because there is electricity, but I don't know how the process is."
2. Identification of Misconceptions
   Misconceptions were observed regarding energy sources and battery function.
   "The battery is the source of electricity, so if it runs out, it means that the electricity is out."
3. Increased Awareness After Training
   Teachers began to recognize gaps in their understanding.
   "It turns out that all this time my explanation is not right."

***Phase 2: Follow-up Mentoring***

Quantitative Results

At the end of mentoring, teachers' ability to design lesson plans and understand concepts was assessed.

**Table 4.** Post-test 2 Results

| Category | Frequency | Percentage |
|---|---|---|
| Passed (≥3) | 16 | 80% |
| Not Passed (<3) | 4 | 20% |

Qualitative Findings (Phase 2)

Two major themes were identified:

1. Improved Ability to Translate Concepts into Practice
   Teachers demonstrated the ability to design simple experiments and lesson plans.
   "I started to be able to create simple experiments for children."
2. Difficulty Explaining Abstract Concepts
   Teachers still struggled with invisible processes such as electric current.
   "The electric current is difficult to explain because it is invisible."

***Phase 3: Pedagogical Mentoring and Classroom Implementation***

Quantitative Results

**Table 5.** Pedagogical Competence

| Category | Frequency | Percentage |
|---|---|---|
| Able | 8 | 40% |
| Adequately able | 9 | 45% |
| Less able | 3 | 15% |

**Table 6.** Student Interest

| School | Percentage |
|---|---|
| A | 55% |
| B | 68% |
| C | 79% |
| D | 76% |
| E | 75% |
| F | 67% |
| **Average** | **70%** |

Qualitative Findings (Phase 3)
Three themes emerged:

1. Variation in Pedagogical Implementation
   Some teachers successfully integrated theory and practice, while others showed partial implementation.
2. Challenges in Classroom Management and Explanation
   Difficulties were observed in maintaining engagement and explaining concepts clearly.
   "I still have trouble explaining when children ask deeper questions."
3. Emergence of Student Inquiry
   Students actively asked questions during practical activities.
   "If the cable is not connected, why is the light off?"

***Explanation of Figures***

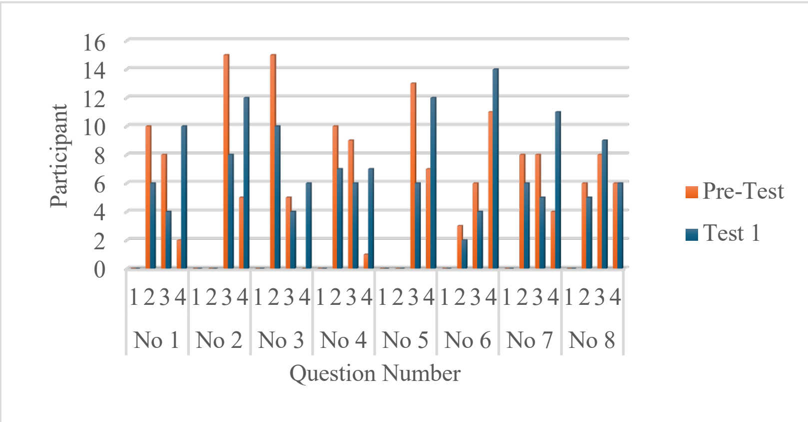


**Figure 4.** Pre-Test and Test-1 Results

The figure illustrates a shift in score distribution, showing fewer teachers in the lowest category and more in the highest category after training.

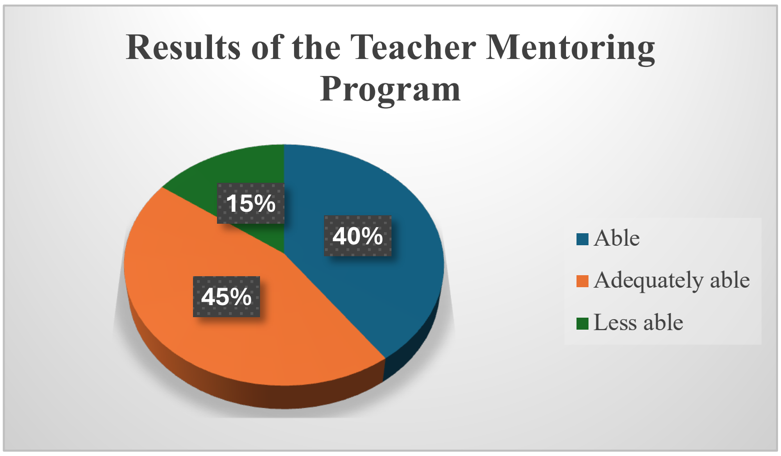


**Figure 5.** Percentage of pedagogical ability of the mentoring participants

The figure presents the proportion of teachers across three competence levels, indicating that most teachers fall into the "adequately able" category.

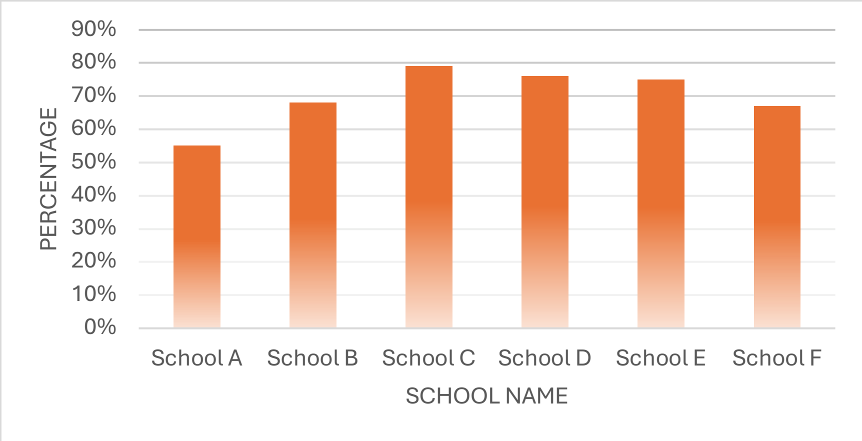


**Figure 6.** Percentage of student interest in each school

The figure shows variation in student engagement across schools, with an overall average of 70%.

## DISCUSSION

### 1. Changes in Teachers' Conceptual Understanding of Electricity

The findings indicate that teachers' understanding of basic electrical concepts improved across the intervention phases, as reflected in the shift from fragmented explanations to more structured and scientifically aligned reasoning. This improvement is important because conceptual clarity forms the foundation for effective science teaching, particularly in early childhood contexts where misconceptions can easily be transmitted to learners. Previous studies have shown that both teachers and students often hold persistent misconceptions about electricity, especially regarding energy sources and electric current (Olaogun et al., 2023). The results of this study are consistent with research suggesting that structured interventions and guided reflection can support conceptual change among teachers (Leuchter et al., 2020). In addition, the integration of training and mentoring appears to support teachers in reconstructing their prior knowledge, which aligns with constructivist perspectives on learning (Jirout & Zimmerman, 2015). However, the improvement observed in this study was limited to basic electrical concepts and did not extend to more complex or abstract topics (Susanto et al., 2020; Wayment & McDonald, 2017). Therefore, while the findings demonstrate positive trends, they should be interpreted within the scope of the intervention content and duration.

### 2. Development of Teachers' Pedagogical Ability

The study found that most teachers were able to design and implement Learn and Play based learning activities, although the level of pedagogical competence varied across participants. This finding is significant because pedagogical content knowledge (PCK) plays a critical role in transforming subject matter into meaningful learning experiences for children. Prior research has emphasized that teachers' ability to integrate content knowledge with pedagogy directly influences learning quality (Gess-Newsome et al., 2019; Schmitt et al., 2023). The results align with studies indicating that experiential and collaborative learning approaches can enhance teachers' instructional practices (Puglisi et al., 2017; Hung et al., 2006). At the same time, the persistence of difficulties in explaining abstract concepts such as electric current suggests that pedagogical improvement requires sustained support beyond initial training. This finding is also consistent with research showing that abstract scientific concepts present unique challenges in early childhood education. Therefore, while the intervention supported pedagogical development, the outcomes remain conditional on continued practice and reinforcement.

### 3. Classroom Implementation and Student Engagement

The classroom implementation phase revealed that student engagement increased in most participating schools, as indicated by active participation and the emergence of inquiry-based questions. This finding is important because engagement and curiosity are key indicators of early scientific thinking and learning readiness. Research has shown that children's curiosity drives exploration and supports the development of scientific reasoning skills (Mukhlis et al., 2024; Loka et al., 2022; Rossbach et al., 2024). The observed increase in student questioning aligns with the literature on play-based learning, which emphasizes the role of active exploration in knowledge construction (Juih et al., 2021; Hidayati, 2021). In this study, the use of simple experiments and real-life contexts appears to have facilitated children's interest in learning about electricity. However, it should be noted that student engagement was not uniform across all schools, indicating variability in implementation quality. Additionally, the study did not directly measure children's conceptual understanding, so the findings are limited to observable engagement rather than learning outcomes.

**Limitations**
This study has several limitations that should be acknowledged. First, the sample size was relatively small and limited to a specific geographic context, which restricts the generalizability of the findings. Second, the duration of the intervention was relatively short, making it difficult to assess long-term retention and transfer of knowledge. Third, the study relied on a combination of test scores and self-reported data, which may introduce potential bias. Fourth, the assessment instruments focused primarily on basic electrical concepts and did not cover broader science domains. Fifth, the absence of inferential statistical analysis limits the ability to make strong claims about the magnitude of change observed. Sixth, variations in classroom implementation may have influenced the results, particularly in the measurement of student engagement. Therefore, these limitations should be considered when interpreting the findings of this study.

**Future Research**
Future research should explore the long-term impact of similar interventions on both teachers and students. Studies with larger and more diverse samples are needed to improve the generalizability of findings. In addition, future research could incorporate experimental or quasi-experimental designs to strengthen causal claims. It would also be valuable to examine how improvements in teachers' understanding influence children's conceptual development in science. Furthermore, integrating digital tools or technology-enhanced learning environments may offer new opportunities for supporting early science education. Research could also investigate how different mentoring models affect teacher development outcomes. Finally, further studies should explore the integration of broader STEM or STEAM approaches in early childhood contexts with stronger empirical support.

**Implications (STEAM framed cautiously)**
The findings of this study suggest that structured training combined with Learn and Play activities can support improvements in teachers' conceptual understanding and pedagogical practice. This implication is consistent with research highlighting the importance of experiential and play-based approaches in early childhood education (Munastiwi et al., 2022; Tekerci et al., 2023). While the study focused specifically on electrical concepts, the results indicate potential for broader application in science learning contexts. The integration of practical activities and real-life experiences appears to support both teacher learning and student engagement. However, recommendations related to STEAM integration should be approached cautiously, as the current study did not directly examine all STEAM components. Existing research suggests that STEAM approaches can enhance interdisciplinary learning, but their effectiveness depends on careful implementation (Long & Davis, 2017; Fonsén & Ukkonen-Mikkola, 2019). Therefore, STEAM should be considered as a potential extension rather than a central conclusion of this study.

## CONCLUSION
This study aimed to examine how a structured Learn and Play–based intervention supported early childhood teachers' understanding of basic electrical concepts and their ability to design developmentally appropriate science activities. The findings show that teachers' conceptual understanding improved across phases, with shifts from experience-based and often inaccurate explanations toward more coherent scientific reasoning, and that most teachers were able to translate this understanding into lesson plans and classroom practices that promoted children's exploratory engagement. These empirically supported gains indicate that guided training and mentoring can strengthen teachers' readiness to introduce foundational science concepts in early childhood settings. A practical implication is that teacher professional development programs can benefit from integrating hands-on exploration, structured mentoring, and opportunities for iterative lesson design. However, the study's limited sample and short intervention duration mean that these findings should be interpreted cautiously and cannot be generalized broadly. Overall, the results demonstrate that strengthening teachers' conceptual and pedagogical foundations through Learn and Play approaches is a promising pathway for enhancing early science learning.

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## AUTHOR CONTRIBUTION STATEMENT

I contributed to conceptualization, methodology, supervision, validation, writing – original draft, and writing – review & editing. I contributed to methodology, formal analysis, investigation, resources, and writing – review & editing. SM contributed to data curation, investigation, project administration, and writing – original draft. All authors have read and approved the final version of the manuscript.

## AI DISCLOSURE STATEMENT

The authors used ChatGPT (OpenAI) during the preparation of this work for limited language editing and grammar improvement. After using the tool, the authors carefully reviewed and revised the manuscript and take full responsibility for the accuracy, integrity, and content of the publication.

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