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The Effectiveness of Cognitive Scaffolding Techniques in Improving Teaching Competency among B.Ed. Trainees

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Abstract

This study examines the effectiveness of cognitive scaffolding techniques in enhancing the teaching competency of B.Ed. trainees specializing in Physical Science at Alagappa University College of Education, Karaikudi, Tamil Nadu, India. A single-group pre-test, treatment, and post-test design was employed, involving 40 pre-service trainees with academic backgrounds in Physics and Chemistry. Cognitive scaffolding strategies, including concept mapping, guided questioning, and iterative feedback loops, were integrated into a three-week training intervention. The Teaching Competency Assessment Scale (TCAS), a validated tool encompassing dimensions such as pedagogical knowledge, classroom management, instructional strategies, and evaluation techniques, was used to measure outcomes. Quantitative analysis using paired sample t-tests revealed a statistically significant improvement in teaching competency scores post-intervention ($t(39) = 12.76, p < 0.001$). These findings align with previous studies, such as those by Kim et al. (2022) and Anand & Mehta (2021), which emphasize the transformative role of scaffolding in fostering reflective teaching practices and critical thinking skills. The intervention demonstrated its utility in bridging the gap between theoretical knowledge and practical classroom applications, particularly in complex domains like Physical Science education. The study underscores the importance of embedding cognitive scaffolding techniques within teacher training curricula to prepare educators capable of effective instructional delivery and student engagement. Further research with diverse cohorts and longitudinal designs is recommended to assess the sustained impact of scaffolding strategies in teacher education.

Keywords: *Cognitive Scaffolding, Teaching Competency, Pre-Service Teacher Training.*

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1. Introduction

Teaching competency is a cornerstone of effective education, particularly in teacher training programs that prepare educators to meet the dynamic demands of modern classrooms. Competent teachers exhibit a balance of subject expertise, the ability to manage diverse classrooms, and the capacity to foster critical thinking among students **(Shulman, 1987)**. However, many teacher education programs face challenges in equipping preservice teachers with practical strategies that bridge the gap between theoretical concepts and real-world classroom scenarios **(Darling-Hammond et al., 2020)**.

Cognitive scaffolding, a pedagogical approach rooted in **Vygotsky's (1978)** Zone of Proximal Development (ZPD), provides temporary, structured support to learners. This support gradually diminishes as learners develop independence in performing tasks. Within the context of teacher education, cognitive scaffolding techniques—such as concept mapping, guided questioning, and iterative feedback—enable trainees to refine their instructional strategies, enhance their problem-solving abilities, and adapt to complex classroom situations.

The Physical Science specialization, which encompasses Physics and Chemistry, is particularly challenging for pre-service teachers. Effective teaching in this domain demands not only mastery of abstract scientific concepts but also the ability to design engaging instructional methods and manage diverse classrooms effectively **(Grossman et al., 2009)**. Despite the rigor of B.Ed. programs, many trainees struggle to implement theoretical knowledge in practical settings, underscoring the need for innovative instructional strategies.

This study investigates the role of cognitive scaffolding techniques in enhancing teaching competency among Physical Science pre-service trainees at Alagappa University College of Education. By employing a single-group pre-test, intervention, and post-test design, the study evaluates how scaffolding strategies facilitate the transition from theoretical understanding to practical application. The findings aim to provide insights into integrating scaffolding techniques into teacher education curricula to prepare competent educators who can meet the evolving needs of students in Physical Science classrooms.

Emerging research underscores the importance of scaffolding in teacher education. For example, **Lin et al. (2023)** found that cognitive scaffolding improved classroom management and instructional adaptability among pre-service teachers. Similarly, a study by **Johnson et al. (2021)** highlighted the positive impact of guided questioning in enhancing trainees' problem-solving skills. Building on these findings, the present study explores the effectiveness of scaffolding techniques in equipping B.Ed. trainees with the skills needed to excel as Physical Science educators.

2. Background Information

2.1. Need and Significance of the Study

Teacher education plays a pivotal role in shaping the quality of education, particularly in subjects like Physical Science, where abstract concepts demand innovative instructional approaches. The increasing complexity of classroom environments, diverse learning needs, and the integration of technology require pre-service teachers to develop a broad range of competencies, including subject knowledge, classroom management, and instructional design. Despite rigorous training, many B.Ed. trainees struggle to apply theoretical knowledge effectively in real-world teaching scenarios, leading to a gap between learning and practice **(Darling-Hammond et al., 2020)**.

Cognitive scaffolding, grounded in **Vygotsky's (1978)** Zone of Proximal Development (ZPD), offers an effective approach to address this gap. By providing structured, temporary support, scaffolding enables learners to perform tasks they initially cannot accomplish independently. Techniques such as guided questioning, feedback loops, and concept mapping have been shown to enhance critical thinking, problem-solving, and adaptability in trainees, all of which are essential for teaching competency **(Lin et al., 2023)**.

2.2. Rationale of the Study

The Physical Science specialization is a demanding field that requires teachers to simplify complex scientific principles and engage students in active learning. However, many pre-service teachers face challenges in mastering instructional strategies, particularly in translating theoretical knowledge into engaging classroom activities. The rationale for this study stems from the need to identify evidence-based interventions that enhance the teaching competencies of Physical Science trainees. Cognitive scaffolding, with its focus on structured support and gradual independence, aligns with the objectives of teacher education and offers a promising solution to these challenges.

2.3. Scope of the Study

This study focuses on B.Ed. trainees specializing in Physical Science at Alagappa University College of Education, Karaikudi. It explores the effectiveness of cognitive scaffolding techniques, including concept mapping, guided questioning, and iterative feedback, in improving their teaching competencies. The research adopts a single-group pre-test, treatment, and post-test design, analyzing the impact of scaffolding on instructional planning, classroom management, and student engagement.

While the study is specific to Physical Science education, its findings have broader implications for teacher training programs across disciplines. By identifying effective scaffolding strategies, the study contributes to the development of pedagogical practices that bridge the gap between theory and practice. Moreover, it underscores the need for integrating cognitive scaffolding into B.Ed. curricula to prepare competent educators capable of meeting the demands of diverse classrooms.

This research is expected to provide actionable insights for teacher educators, curriculum developers, and policymakers to enhance the quality and relevance of teacher education programs.

3. Literature Review

3.1. Cognitive Scaffolding in Education

Cognitive scaffolding refers to the temporary support provided to learners to help them complete tasks they cannot do independently, and is rooted in **Vygotsky's (1978)** sociocultural theory. This support can include techniques such as modeling, guided questioning, and feedback, which are gradually removed as learners become more capable **(Wood et al., 1976)**. Recent research underscores the role of cognitive scaffolding in enhancing problem-solving skills **(Kim et al., 2022)** and fostering metacognitive abilities **(Hattie, 2021)**. These findings suggest that scaffolding is a powerful tool for improving learners' cognitive and problem-solving capabilities.

3.2. Teaching Competency

Teaching competency is a multifaceted construct that includes pedagogical knowledge, effective instructional strategies, classroom management, and the ability to assess student learning **(Shulman, 1986)**. Studies indicate that structured interventions such as microteaching and cognitive scaffolding can significantly improve teaching competency **(Kumar et al., 2021)**. These methods help educators develop a deeper understanding of instructional practices and enhance their ability to engage students effectively in the learning process.

3.3. Application in Pre-service Teacher Training

In pre-service teacher training, there is often insufficient emphasis on integrating cognitive skills with pedagogical strategies **(Rajendran, 2020)**. However, scaffolding techniques can be beneficial for teacher trainees in understanding the complexities of lesson planning, teaching, and assessment. By incorporating cognitive scaffolding, trainees can develop a more nuanced approach to teaching, enhancing their ability to design and deliver effective lessons **(Anand & Mehta, 2021)**.

3.4. Review Summary

The literature consistently supports the use of cognitive scaffolding in enhancing teaching competencies. While its impact on general teaching practices is well-documented, its application in Physical Science teacher training remains underexplored, highlighting the need for further empirical studies to investigate its potential benefits in this specific domain.

4. Objectives of the study

- To assess the pre-intervention teaching competency levels of B.Ed. trainees specializing in Physical Science.
- To design and implement cognitive scaffolding strategies, including concept

mapping, guided questioning, and feedback loops, to enhance teaching competency.

- ❖ To evaluate the post-intervention improvement in teaching competency among B.Ed. trainees.
- ❖ To determine the specific dimensions of teaching competency (pedagogical knowledge, instructional strategies, classroom management, and evaluation techniques) most affected by cognitive scaffolding.
- ❖ To provide recommendations for incorporating cognitive scaffolding techniques into teacher education curricula.

5. Hypotheses

- ❖ There is no significant difference in the teaching competency of B.Ed. trainees before and after the implementation of cognitive scaffolding techniques.
- ❖ There is a significant improvement in the teaching competency of B.Ed. trainees after the implementation of cognitive scaffolding techniques.

6. Operational Definitions of Key Terms

- ❖ **Cognitive Scaffolding:** Refers to structured strategies that assist learners in accomplishing complex tasks they cannot complete independently. Techniques such as concept mapping, guided questioning, and iterative feedback loops are used in this study to enhance teaching competency.
- ❖ **Teaching Competency:** The ability of B.Ed. trainees to effectively demonstrate pedagogical knowledge, manage classrooms, employ instructional techniques, and assess student learning. This competency is measured using the Teaching Competency Assessment Scale (TCAS).
- ❖ **Pre-service Teacher Training:** A formal educational program designed for B.Ed. trainees, focusing on pedagogy, instructional methods, and subject-specific teaching practices. This training prepares trainees for professional teaching roles in schools.
- ❖ **Physical Science Education:** A specialized discipline dedicated to teaching Physics and Chemistry concepts. It requires the application of targeted pedagogical strategies to engage students and effectively communicate abstract scientific ideas.
- ❖ **B.Ed. Trainees:** Students enrolled in the Bachelor of Education program specializing in Physical Science at Alagappa University College of Education. These trainees are preparing for professional teaching careers in the field of Physical Science education.

7. Methodology

7.1. Research Design This study utilized a single-group pre-test, treatment, and post-test design. The participants underwent a pre-test to assess baseline teaching competency, followed by a three-week intervention using cognitive scaffolding techniques. A post-test was conducted to evaluate the effectiveness of the intervention.

7.2. Participants The study involved 40 B.Ed. trainees specializing in Physical Science (Physics and Chemistry graduates) at Alagappa University College of Education, Karaikudi. The participants were selected using purposive sampling.

7.3. Instruments A Teaching Competency Assessment Scale (TCAS) was developed and validated for this study. The TCAS comprised four dimensions:

S.No	Teaching Competency Dimensions	No of Statements
1	Pedagogical Knowledge (10 items)	10
2	Classroom Management (10 items)	10
3	Instructional Strategies (10 items)	10
4	Evaluation Techniques (10 items)	10

7.4. Intervention

The cognitive scaffolding intervention in this study was designed to enhance the teaching competency of B.Ed. trainees, focusing on the application of specific instructional strategies. The intervention employed three primary techniques: concept mapping, guided questioning, and feedback loops, each of which played a significant role in supporting the trainees' learning and development.

- **Concept Mapping:** Concept mapping is a visual technique that helps learners organize and represent knowledge in a structured manner. In this intervention, trainees were required to create concept maps to outline and present lesson content. This technique encouraged them to break down complex ideas into manageable components, which not only facilitated deeper understanding but also helped them identify key concepts and relationships between different parts of the curriculum. By using concept maps, trainees were able to visualize the structure of their lessons, making it easier to design coherent and organized teaching plans. Additionally, concept mapping enhanced their ability to explain abstract scientific concepts clearly and effectively.
- **Guided Questioning:** Guided questioning is a technique in which facilitators use probing questions to stimulate critical thinking and reflection. During the intervention, facilitators asked trainees questions related to lesson preparation, which prompted them to think critically about their instructional choices and the underlying principles of their teaching methods. This approach helped trainees move beyond surface-level understanding, encouraging them to engage with the content more deeply and consider alternative perspectives. The use of guided questioning also promoted metacognitive skills, as trainees were encouraged to assess their own thinking and refine their teaching strategies.
- **Feedback Loops:** Feedback loops involved the provision of constructive feedback following microteaching sessions, where trainees demonstrated their lesson plans in practice. Facilitators provided timely, specific, and actionable feedback on various aspects of teaching, including lesson delivery, classroom management, and student engagement. This feedback allowed trainees to reflect on their strengths and areas for improvement, promoting continuous learning. The iterative nature of feedback loops helped reinforce positive teaching practices while addressing weaknesses, ultimately contributing to the trainees' professional growth.Together, these cognitive scaffolding techniques created a supportive learning environment that facilitated the development of key teaching competencies among the B.Ed. trainees.
- Data Analysis Data were analyzed using paired sample t-tests to compare pre-test and post-test scores. Effect sizes were calculated to determine the practical significance of the intervention.

8. Results and Discussion

8.1. Pre-Test and Post-Test Comparison

Table 1. Comparison of Pre-Test and Post-Test Scores

Measure	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-value	p-value
Overall Competency	52.45 (6.32)	78.85 (5.98)	12.76	<0.001

The results of the pre-test and post-test comparison, measured through the Teaching Competency Assessment Scale (TCAS), reveal a significant improvement in the overall teaching competency of the B.Ed. trainees. The mean score on the TCAS increased from 52.45 (SD = 6.32) in the pre-test to 78.85 (SD = 5.98) in the post-test. This change was statistically significant, as indicated by the paired sample t-test ($t(39) = 12.76$, $p < 0.001$), highlighting a substantial enhancement in the trainees' teaching competency after undergoing the cognitive scaffolding intervention. These findings suggest that the scaffolding techniques applied in the study played a key role in improving the overall teaching performance of the trainees.

8.2. Dimension-Wise Analysis

Table-2: Dimension-Wise Comparison of Scores

Dimension	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-value	p-value
Pedagogical Knowledge	12.05 (2.10)	18.50 (1.95)	9.32	<0.001
Classroom Management	13.30 (1.85)	19.10 (1.70)	10.45	<0.001
Instructional Strategies	13.00 (2.00)	20.00 (1.80)	11.78	<0.001
Evaluation Techniques	14.10 (2.05)	21.25 (1.90)	10.12	<0.001

In addition to the overall improvement, a detailed analysis of the four dimensions assessed in the TCAS—Pedagogical Knowledge, Classroom Management, Instructional Strategies, and Evaluation Techniques—also showed significant progress. For instance, the mean score for Pedagogical Knowledge increased from 12.05 (SD = 2.10) in the pre-test to 18.50 (SD = 1.95) in the post-test, with a t-value of 9.32 ($p < 0.001$). Similar improvements were observed in Classroom Management (t-value = 10.45, $p < 0.001$), Instructional Strategies (t-value = 11.78, $p < 0.001$), and Evaluation Techniques (t-value = 10.12, $p < 0.001$). These results suggest that cognitive scaffolding not only enhanced the overall teaching competency but also targeted specific teaching areas, improving trainees' skills across multiple dimensions of teaching practice.

8.3. Discussion

The findings of this study are consistent with previous research on cognitive scaffolding in educational contexts. Studies such as Kim et al. (2022) and Hattie (2021) have emphasized the positive impact of cognitive scaffolding on enhancing problem-solving abilities and fostering metacognitive skills. In this study, the use of concept mapping facilitated the organization and presentation of lesson content, enabling trainees to better structure their teaching materials. Guided questioning promoted critical thinking and encouraged trainees to reflect on their teaching strategies, leading to more informed instructional decisions. Feedback loops, a crucial aspect of cognitive scaffolding, provided ongoing support and allowed trainees to make iterative improvements based on constructive feedback during microteaching sessions.

These results underscore the value of integrating scaffolding techniques into teacher education programs. The significant improvements observed in the dimensions of pedagogical knowledge, classroom management, instructional strategies, and evaluation techniques suggest that scaffolding not only enhances the overall teaching competency of teacher trainees but also strengthens specific teaching skills that are crucial for effective classroom practice. Thus, this study reinforces the importance of incorporating scaffolding strategies into teacher education curricula to better prepare trainees for the demands of teaching and improve their professional development.

9. Implications

The findings of this study have important implications for teacher education programs. Integrating cognitive scaffolding techniques into preservice teacher training can significantly enhance the quality of instruction by providing trainees with structured support that helps them develop key teaching competencies. The use of scaffolding strategies, such as concept mapping, guided questioning, and feedback loops, encourages reflective and critical thinking, enabling trainees to assess and improve their teaching methods continuously. Moreover, scaffolding equips trainees with practical, effective strategies for classroom instruction, helping them navigate complex teaching tasks with greater confidence and skill. By incorporating these techniques into teacher education curricula, programs can better prepare future educators, fostering more effective, reflective, and well-equipped teachers who can meet the diverse needs of their students. This approach can ultimately improve teaching practices and outcomes in various educational settings.

10. Limitations and Recommendations

The study presented several limitations that may influence the interpretation and generalization of the findings. First, the research was limited to a single group of Physical Science trainees, which may restrict the ability to generalize the results to other subject areas or diverse groups of teacher trainees. Since the sample was specific to Physical Science, the findings may not fully apply to trainees from other disciplines. Given these limitations, several recommendations can be made for future research. First, it would be valuable for subsequent studies to explore the effects of cognitive scaffolding across a variety of subject groups. Investigating how scaffolding techniques impact trainees in subjects beyond Physical Science could provide a more comprehensive understanding of its effectiveness in diverse educational contexts. Additionally, the study's short-term nature highlights the need for longitudinal research to assess the sustained impact of cognitive scaffolding on teaching competency over time. Longitudinal studies would provide insights into whether the improvements in teaching skills persist and whether the benefits of scaffolding continue to influence teaching practices beyond the immediate post-test phase. Such research would contribute to a deeper understanding of the long-term value of scaffolding in teacher education. By addressing these limitations and exploring these recommendations, future research can further enhance the body of knowledge on cognitive scaffolding and its role in developing effective teaching competencies.

11. Conclusion

This study highlights the effectiveness of cognitive scaffolding techniques in improving teaching competency among B.Ed. trainees specializing in Physical Science. The results show that scaffolding methods, such as concept mapping, guided questioning, and feedback loops, significantly enhance critical thinking, reflective practice, and instructional skills. These findings suggest that cognitive scaffolding is a promising approach for teacher training programs, offering valuable support for trainees to develop essential teaching competencies. Moreover, the study underscores the importance of integrating these techniques into teacher education curricula for sustained professional development. By fostering both the knowledge and confidence of future educators, cognitive scaffolding plays a crucial role in preparing competent teachers who are capable of adapting to diverse classroom challenges and improving student outcomes. The study advocates for the continued use and expansion of these methods to strengthen teacher training and teaching practices.

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