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Enhancing Pedagogical Competence in Inclusive Early Childhood Education through Interactive Digital Modules: A Pre-Experimental Study

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Inclusive Education, Pedagogical Competence, Interactive-Digital Modules, Early Childhood Teacher.

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Abstract
One of the primary challenges in early childhood education (ECE) is ensuring that teachers possess the necessary pedagogical competence to effectively support diverse learners, particularly in inclusive education settings where students with special needs require tailored teaching strategies. This study explores the effectiveness of interactive digital modules in enhancing the pedagogical competence of early childhood education (ECE) teachers in inclusive settings. Using a quantitative pre-experimental design, 70 teachers from 12 inclusive ECE institutions participated in pre-and post-tests to assess their pedagogical skills before and after module exposure. Results show a significant increase in post-test scores, with an average improvement from 50 to 89, confirmed by a paired sample t-test ($p < 0.01$). The N-Gain analysis revealed a high level of effectiveness, with an average score of 0.78, indicating that the modules substantially improved teacher competencies. However, the lack of a control group limits the study's ability to attribute improvements solely to the intervention. Other factors, such as previous teaching experience or additional resources, may have influenced the outcomes. Despite this limitation, the findings suggest that interactive digital modules are valuable for advancing pedagogical skills in inclusive education. These results have important implications for teacher professional development, supporting integrating of digital tools into ECE teachers' training programs. Future research should employ more rigorous experimental designs, including control groups, to better isolate the impact of digital modules and investigate their long-term effects on teaching competence and student outcomes in inclusive environments.

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Introduction

Early childhood education (ECE) represents a foundational stage in human development, often referred to as the "golden period" due to its critical impact on cognitive, emotional, and social growth (Bai et al., 2020). Promoting inclusive education within ECE is crucial for fostering environments where all children, regardless of their abilities, can learn and thrive. Inclusive ECE programs emphasize respecting children's rights and embracing cultural and individual differences, especially those with special needs (Bulut, 2021; Jiao et al., 2022). ECE teachers are pivotal in facilitating these inclusive environments, tailoring educational approaches to meet the diverse needs of children (D'Agostino & Douglas, 2022). However, many teachers face significant challenges in delivering inclusive education due to a lack of resources, training, and support, making it an urgent issue for educational systems worldwide (Sucuoğlu & Bakkaloğlu, 2018).

Pedagogical competence is a crucial requirement for ECE teachers, particularly in inclusive settings, where understanding the unique needs of children is essential (Morrison, 2018). This competence includes mastery of educational content and adapting learning environments to promote inclusive development for all children (Bøe et al., 2022). Teachers must have skills to

recognize and address each child's varied learning capacities and needs, especially in settings where cultural, socioeconomic, and developmental differences are prevalent (Diatlenko et al., 2021). Previous studies have demonstrated that pedagogical competence directly influences the effectiveness of inclusive education by enabling teachers to implement personalized teaching strategies (Ranta et al., 2023). Nevertheless, many educators lack the necessary tools and knowledge to implement these practices effectively in real-world classroom settings (Zhang & Zhang, 2020).

Despite widespread recognition of the importance of inclusive education, numerous challenges persist in its practical implementation. Teachers in ECE settings often face substantial workloads, making it challenging to manage the diverse learning needs of all children, particularly those with special needs (Figueiredo et al., 2023; Saminder Singh et al., 2023). Moreover, training programs for ECE teachers frequently fall short of providing the specialized skills required to deliver high-quality, inclusive education (Gezer & Aksoy, 2019). Infrastructure and resource limitations further exacerbate these challenges, as many schools lack the physical and instructional materials needed to support inclusive practices (Fertika et al., 2022). Teachers' limited access to professional development programs focused on inclusive education contributes to ongoing disparities in educational equity (Dignath et al., 2022).

To address these gaps, developing digital learning tools, such as interactive digital modules, has emerged as a promising approach to enhancing teacher training and pedagogical competence in inclusive education (Tarigan et al., 2023). Digital modules provide flexible, accessible platforms for teachers to engage with educational content at their own pace, offering a practical solution for continuous professional development (Guillaume et al., 2022; Srisawat & Wannapiroon, 2022). Using interactive elements, such as videos, quizzes, and real-time feedback, enhances the learning experience and makes these tools more effective in promoting understanding complex topics like inclusive education (Syahfitri, 2024). Studies have shown that digital tools are particularly beneficial in contexts where traditional training programs are inaccessible or inadequate (Harfiani & Akrim, 2020). By leveraging digital technology, educational institutions can provide teachers with the resources they need to develop inclusive pedagogical skills (Fitriana et al., 2023).

Integrating digital tools into teacher education has shown significant potential for improving pedagogical competence in various educational contexts. For example, interactive digital modules allow teachers to engage with course material self-directedly, increasing retention and application of knowledge (Syahfitri, 2024). In the context of inclusive education, digital modules can help bridge the knowledge gap by providing teachers with concrete strategies for designing and implementing inclusive curricula (Tarigan et al., 2023). Furthermore, digital platforms offer the advantage of scalability, allowing for the widespread dissemination of educational resources without the logistical constraints associated with traditional training programs (Shofa, 2018). These tools can also be continuously updated to reflect new research and best practices in inclusive education, ensuring teachers can access the most current information (Fertika et al., 2022).

Although digital modules have demonstrated the potential to enhance teacher training, there is still a lack of empirical evidence on their effectiveness in improving pedagogical competence, specifically for inclusive education in ECE settings (Chu, 2022). Most studies on digital tools have focused on general teacher education without delving into the specific requirements for inclusive pedagogical strategies (Cohen & Kalthoff, 2021). Additionally, while digital tools offer flexibility, there is a concern about equitable access to technology, particularly in low-resource settings where internet connectivity and digital literacy may be limited (QIU, 2018). Moreover, many digital modules are not tailored to teachers' specific cultural and contextual needs, limiting their applicability in diverse educational environments (Khayankij, 2023). Addressing these gaps requires more focused research on digital tools' design, implementation, and impact in promoting inclusive education in early childhood settings.

This study aims to investigate the impact of interactive digital modules on the pedagogical competence of ECE teachers in implementing inclusive education. By focusing on how these digital tools can enhance teachers' ability to understand and apply inclusive educational practices, this research seeks to address a critical gap in the literature. The study will evaluate the effectiveness of interactive digital modules in promoting practical, real-world application of inclusive pedagogical strategies. Findings from this study are expected to contribute to the broader discourse on teacher training in inclusive education, offering evidence-based recommendations for integrating digital tools into professional development programs. Ultimately, this research will provide valuable insights for policymakers, educators, and researchers looking to improve the quality of inclusive education in early childhood settings through innovative digital technologies.

Methods

This research uses a quantitative approach with the Pre-Experimental Design research type. Pre-experimental design research has not been categorized as a perfect experiment because external variables still influence the formation of dependent variables (Sugiyono, 2016). The research sample was obtained through purposive sampling with a total sample of 70 ECE teachers from 12 ECE institutions in the Jebres sub-district, which are included in inclusive ECE and have students with special needs. The research design used was a group pretest-posttest design. This design is depicted in Figure 1 below:

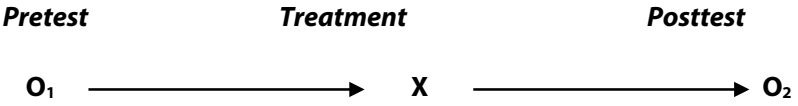

Figure 1. Research Design

Description:
O_1 : Pre-test score (Before treatment)
X : *Treatment*
O_2 : Post-test score (after treatment)

The instrument used in this research is a test. The test was used to obtain data on the pedagogical competence of early childhood education (ECE) teachers through a written test. Before the instrument was used, it was tested to determine its validity and reliability (Arifin, 2017). Furthermore, the results of the test instrument were analyzed. Data collection techniques in this study were carried out through observation, tests, and interviews. After the data was obtained, data analysis was carried out. Data analysis techniques in this study used descriptive quantitative and inferential analysis using the gain score test and paired sample t-test through SPSS to calculate whether there was a difference in pre-test and post-test scores and to determine the effectiveness of using interactive digital modules for ECE-inclusive education in improving the pedagogical competence of ECE teachers (Hake, 1999). The following is the formula for calculating the gain score test:

$$<g> = \frac{\%Sf - \%\,Si}{100 - \%Si}$$

Figure 2. Gain Score Test Formula

Description:
<g> = gain score
Sf = mean post-test score
Si = mean pre-test score

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Table 1 below describes the pretest and post-test questions that researchers used to collect data to determine the effectiveness of interactive digital modules for ECE-inclusive education in improving the pedagogical competence of ECE teachers.

Table 1. The Topics of Pretest and Post-Test Questions

No	The topic of Pre-test and Post-Test Questions	Question Number
1	Competence of early childhood education (ECE) teachers	1,2
2	Basic concepts of early childhood inclusive education	3-8
3	Types of learners with special needs in ECE	9-13
4	Components of implementing early childhood inclusive education	14-18
5	ECE inclusive education implementation support system	19-20

Testing the instrument's validity is done by calculating using the Product Moment Correlation technique, which shows that the instrument is valid where $r_{count} > r_{table}$ with a significant level of 0.01. The instrument's reliability was tested using Cronbach's Alpha technique, which showed that the instrument was reliable where $r_{11} \geq 0.7$.

Table 2. Instrument Reliability Results

Reliability Statistics	
Cronbach's Alpha	N of Items
.745	20

Furthermore, the following table categorizes the analysis results using the standard value of Gain.

Table 3. Categorization of Analysis Results Using Standard Gain Values (Hake, 1999)

Value	Category
g ≥ 0,7	High (Effective)
0,7 > g ≥ 0,3	Medium (Effective Enough)
g < 0,3	Low (Ineffective)

Result

This section presents the findings from the pre-test and post-test activities conducted to assess the effectiveness of the interactive digital module on inclusive education for Early Childhood Education (ECE) in enhancing the pedagogical skills of ECE teachers. The study utilized a pre-experimental design involving 70 ECE teachers, comparing their pedagogical abilities before and after using the interactive digital module.

The pre-test was conducted initially to assess the teachers' baseline pedagogical competence related to inclusive education in ECE. After the pre-test, the teachers were provided with the interactive digital module, accessible via a link shared through the WhatsApp application. Teachers were given one week to study the module independently. Upon completion of the study period, a post-test was administered to evaluate any improvements in their pedagogical competence.

The pre-test results showed that the average score obtained by the teachers was 50. After studying the interactive digital module for one week, the post-test results revealed a significant increase in the average score, which rose to 89. The comparison between the pre-test and post-test scores is illustrated in the following figure:

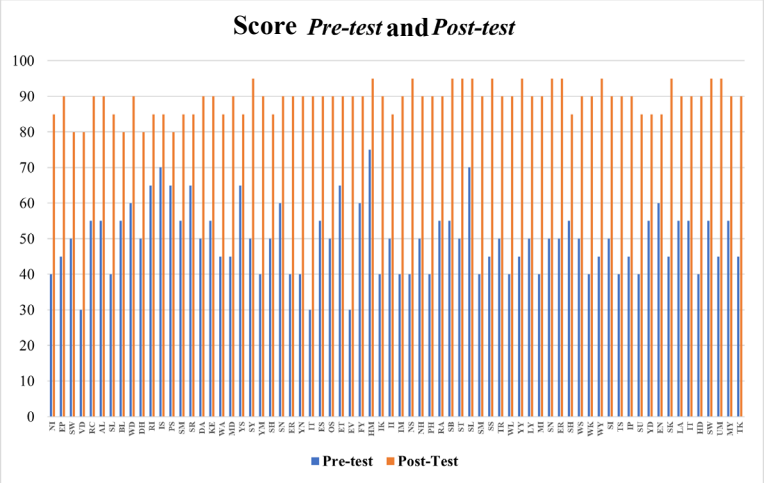

Figure 3. Pre-test and post-test Score

A Paired Samples T-Test was conducted to statistically evaluate the significance of the differences between the pre-test and post-test scores. The Sig. (2-tailed) value of <0.01 indicates a statistically significant difference between the pre-test and post-test results, confirming that using the interactive digital module significantly improved the pedagogical competence of ECE teachers.

Table 4. Results of paired sample T-Test output table

Paired Samples Test								
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1 Pre Test - Post Test	-39.571	10.691	1.278	-42.121	-37.022	-30.967	69	<.001

To further analyze the effectiveness of the interactive digital module in improving pedagogical competence, the pre-test and post-test scores were analyzed using the N-Gain formula. The following table presents the results of processing the teachers' scores based on the N-Gain values:

Table 5. Results of Processing Teacher Pre-test and Post-test Values Based on Gain Value

	Score		*N-Gain*	Category
	Pretest	***Posttest***		
Highest Score	75	95	0,92	High
Lowest Score	30	80	0,43	Medium
Total	3480	6250	54	Medium
Average	50	89	0,78	High

The table shows that the pre-test and post-test scores significantly increased after the ECE teachers were exposed to the interactive digital module on inclusive education. The average N-Gain value of 0.78, classified as high, indicates that the module effectively improved the teachers' pedagogical competence.

The increase in average scores from 50 (pre-test) to 89 (post-test) demonstrates that the interactive digital module on inclusive education positively improved the teachers' understanding of inclusive education in ECE. The results of the Paired Samples T-Test confirm the significance of this improvement. Furthermore, the N-Gain analysis corroborates the module's effectiveness, although the degree of improvement varied among teachers, ranging from medium to high.

While the results indicate significant improvements, several limitations should be noted. A pre-experimental design without a control group limits the ability to attribute the observed improvements solely to the module. Other factors, such as teachers' prior experience or access to additional resources, may also have contributed to the increase in scores. Future research with a more diverse sample and a more extended observation period would strengthen the validity of these findings. In conclusion, the study shows that the interactive digital module on inclusive education effectively enhanced the pedagogical competence of ECE teachers. However, further studies with more rigorous experimental designs are needed to confirm these results..

Discussion

This study aimed to investigate the effectiveness of interactive digital modules in improving the pedagogical competence of Early Childhood Education (ECE) teachers in inclusive education settings. Previous research has consistently highlighted the difficulties ECE teachers face in implementing inclusive education due to limited pedagogical skills and inadequate resources (Pan et al., 2021; Tan & Zheng, 2022). Pedagogical competence, which involves understanding child development, managing classrooms, and applying inclusive practices, is essential for ECE teachers (Ayuna & Gintings, 2023; Mumpuniarti et al., 2020). However, traditional resources have been insufficient in enhancing these skills, prompting the need for innovative solutions like digital modules (Aoki, 2022; Pahlevi et al., 2024). Introducing these interactive digital modules offers a promising approach to overcoming these challenges by providing teachers with accessible, flexible, and tailored learning experiences (Chen, 2018; Syahfitri, 2024).

The results of this study demonstrated a significant improvement in teachers' pedagogical competence after using the interactive digital modules. Pre-test scores averaged 50, which rose to 89 post-tests, reflecting a marked improvement in competence. A Paired Samples T-Test confirmed the statistical significance of these improvements with a Sig. (2-tailed) value of less than 0.01. The N-Gain analysis further reinforced the effectiveness of the modules, yielding an average score of 0.78, categorized as high. Interestingly, the results revealed varying degrees of improvement, with some teachers showing moderate gains (N-Gain 0.43) and others achieving high gains (N-Gain 0.92), underscoring the adaptability of the digital modules to individual learning needs.

These findings align with previous studies on the effectiveness of digital learning tools in improving teachers' competencies. For example, Sulman et al. (2023) found that incorporating technology into teacher training enhanced pedagogical competence in classroom settings. Similarly, Komalasari et al. (2019) demonstrated that multimedia learning resources, such as videos and interactive content, significantly improve teachers' understanding of inclusive practices. Metscher et al. (2021) further confirmed that digital tools can increase engagement and comprehension in inclusive education. The significant improvement observed in this study supports these earlier findings, suggesting that digital modules offer a robust mechanism for professional development in inclusive education.

Conversely, this study contrasts with the findings by Tan and Zheng (2022), who reported that many ECE teachers lack an adequate understanding of inclusive education. The significant improvements seen in this research suggest that interactive digital modules may be more effective than traditional methods in addressing these gaps. Aoki (2022) and Rahman & Maemonah (2019) highlighted the limited resources available to ECE teachers in inclusive education, a challenge that the digital modules in this study successfully addressed. The modules may have provided the depth of understanding required to bridge the knowledge gap identified in prior research by offering a more comprehensive and engaging format.

The effectiveness of these interactive digital modules can be attributed to their design, which incorporates multimedia elements that cater to various learning styles. Research by Shumilova et al. (2022) supports the idea that interactive learning modules, especially those integrating text, video, and animation, enhance teacher understanding and retention.

Furthermore, the flexibility of the modules, allowing teachers to learn at their own pace, likely contributed to the significant gains observed (Ahmad et al., 2024; Fu & Satrianawati, 2022). However, this pre-experimental study's lack of a control group requires cautious interpretation, as external factors like prior teacher experience or access to other resources may have influenced the results. Future studies should better include a control group to isolate digital modules' effects on pedagogical competence.

Additionally, the modules' flexibility in adapting to individual teacher needs explains the wide range of improvements noted, with some teachers showing moderate and others high levels of competence gain. Anisimova (2020) noted that interactive modules that allow self-paced learning are particularly effective for adult learners, who can revisit complex content and apply it to their specific teaching contexts. However, it is essential to consider other factors, such as teachers' prior exposure to inclusive education and their ongoing professional development efforts, which may have contributed to these results. As such, further research utilizing randomized controlled trials would provide more definitive evidence of the modules' long-term effectiveness (Boichuk & Boiarska-Khomenko, 2022; Shumilova et al., 2022).

The findings of this research have important implications for the future of teacher professional development in inclusive education. Integrating interactive digital modules into ECE teacher training programs can significantly enhance pedagogical competence and better equip teachers to meet the diverse needs of children in inclusive settings (Lim et al., 2024; Taufik et al., 2019). Furthermore, the successful implementation of these modules points to the need for educational institutions to invest in digital learning tools as part of their continuous professional development strategies (Maman et al., 2016). Regular monitoring and evaluation of these tools will ensure their ongoing effectiveness and lead to improvements in teacher competence and student outcomes. Expanding interactive digital modules may ultimately transform inclusive education by providing accessible, scalable, and engaging learning solutions for teachers.

Conclusion

his study aimed to improve the pedagogical competence of early childhood education (ECE) teachers in inclusive education settings through interactive digital modules. The findings demonstrate a significant improvement in teacher competence, as evidenced by an increase in average pre-test scores from 50 to 89 in the post-test. The results of the Paired Samples T-Test indicated a statistically significant difference between pre-test and post-test scores, confirming the positive impact of the interactive digital modules on pedagogical competence. The N-Gain analysis, with an average score of 0.78, further supports the effectiveness of the modules, with improvements ranging from moderate to high levels of competence. These results suggest that integrating interactive digital modules into ECE teacher training programs can significantly enhance pedagogical skills and better prepare teachers to meet diverse needs in inclusive settings. However, without a control group, the study's pre-experimental design limits the attribution of the improvements solely to the modules, as other factors like prior experience or access to resources may have contributed. Future research should adopt more rigorous designs and explore these tools' long-term effects and scalability to maximize their potential impact on inclusive education.

Declarations

Author contribution statement

Widiastuti: Conceptualization, design, analysis, writing, critical revision of the manuscript, data analysis/interpretation, securing funding. Hermanto: Technical or material support, supervision, and review.

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