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Effectiveness of ICT-integrated pedagogy on pre-service teachers' teaching competence in mathematics

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The influence of teachers' teaching competence on students' academic performance is pivotal, prompting an examination of the efficacy of ICT-integrated pedagogy in enhancing the teaching competence of pre-service mathematics teachers. This quasi-experimental research employed a pre-test, and post-test control group design involving 30 pre-service teachers, with 15 participants assigned to both the experimental and control groups. Throughout a four-week duration, the experimental group received instruction utilizing 'ICT-integrated pedagogy,' while the control group was taught applying traditional 'Lecture-based pedagogy.' Employing a 'Mathematics Teaching Competence Scale,' both cohorts were assessed prior to and following the intervention, with data subjected to analysis using descriptive statistics and t-tests in SPSS version 20. The results revealed that pre-service teachers in the experimental group, exposed to 'ICT-integrated pedagogy,' demonstrated superior mathematics teaching competency compared to their counterparts in the control group. These findings advocate for the positive impact of ICT-integrated pedagogical approaches in nurturing the teaching proficiency of pre-service teachers. Consequently, this study suggests the widespread implementation of this approach by Teacher Educators, envisioning its potential to engender competent and high-quality teachers.

KEYWORDS

ICT-integrated pedagogy, pre-service teachers, mathematics teaching competence, teaching mathematics, quasi-experiment design

1 Introduction

1.1 Enhancing teaching competence through teacher education

In the current educational landscape, a primary focus for teacher educators lies in equipping pre-service teachers with fundamental competencies essential for effective classroom instruction. This emphasis is particularly pronounced due to the significant and direct influence of teachers' professional competence on both the quality of instruction and the academic achievements of students, especially in the field of mathematics (Escandón, 2021; Yang and Kaiser, 2022). The attainment of high levels of instructional quality necessitates a solid foundation of knowledge and skills among educators (Blömeke et al., 2020). The variability in the proficiency of mathematics teaching competencies exhibited by pre-service teachers is inherently linked to the nature of institutional training and the opportunities provided to enhance these competencies (Smith et al., 2017; Ningtiyas, 2018). In the 21st century, characterized by a paradigm shift from content-centric to competency-based approaches, and from knowledge acquisition to the cultivation of creativity, educators are compelled to move beyond the traditional role of information dissemination. This shift underscores the indispensable need for an evolution in pedagogical processes within the educational framework.

Teachers today are expected to possess a diverse set of competencies to effectively navigate the complex challenges of the contemporary world (Nessipbayeva, 2012). A proficient teacher, equipped with a multifaceted skill set, plays a pivotal role in engendering productive and successful students (Gümüs, 2022). Consequently, there exists a compelling need to systematically nurture and enhance the teaching competencies of educators at the pre-service level (Meenakumari and Premalatha, 2020). Existing literature highlights that pre-service mathematics teachers have demonstrated proficiency in subject matter knowledge (Lee et al., 2018). However, they have been observed to lack comprehensive proficiency in essential pedagogical skills, as perceived by cooperating teachers (Roble and Bacabac, 2016). These skills encompass various facets, including lesson planning activities, classroom management, instructional strategies, motivation, communication skills, questioning techniques, and professionalism (Roble and Bacabac, 2016). Ismail and Jarrah (2019) found that pre-service teachers' practical teaching experiences positively influenced their pedagogical preferences, teaching competence, and motivation to pursue teaching as a future career. Similarly, the teaching practice of pre-service teachers played a pivotal role in shaping their knowledge and expertise in teaching mathematics (Smith et al., 2017), with many mathematics teachers tracing the roots of their competence back to their experiences during teaching practice (Makamure and Jita, 2019). Practicing teachers have also furthered their proficiency in transforming instructional objectives, selecting tasks, and executing them, while concurrently refining their professional vision to align with reform-oriented curricula through parallel lesson study (Huang and Han, 2015). Additionally, the incorporation of innovative assignments focusing on creativity and cognitive flexibility has been shown to heighten the likelihood of future teachers demonstrating a positive attitude toward mathematics (De-La-Peña et al., 2021). However, Graham et al. (2020) found, in their investigation, that there is no clear correlation between teaching experience and teaching quality. Instead, there is some evidence suggesting a decline in teaching quality among teachers with 4–5 years of experience.

In contrast, Lowrie and Jorgensen (2016) explored that despite variations in mathematics content knowledge levels, pre-service teachers' attitudes and beliefs associated with mathematics education practices remained largely unchanged. Fernández-Cézar et al. (2020) demonstrated that factors such as educational level and type of hiring of teachers determine teachers' level of anxiety and belief toward mathematics. Nonetheless, it is plausible to shift negative predispositions toward mathematics toward a more positive orientation through the exploration of the mechanisms linking negative emotions with mathematics (Hannula, 2002). Moreover, students' negative emotional disposition toward mathematics may vary in accordance with different patterns of attitude, contingent upon their perceived competence and conception of mathematics, as well as the interplay among these three dimensions (Di Martino and Zan, 2011). Barribal et al. (2022) revealed that exposure to input enhancement training programs had a significant positive impact on pre-service teachers' teaching of mathematical comprehension/word problems, along with a moderate effect on their pedagogical competence and approaches in teaching mathematical comprehension. Beswick and Fraser's (2019) findings highlighted that by encouraging novice teachers to thoroughly deliberate on what they require to comprehend, explore, or reflect upon throughout the stages of planning, implementation, and reflection in teaching, their competency in 21st-century skills could be cultivated.

1.2 Integrating information and communication technology to enhance pedagogical competence

Information and Communication Technology (ICT) has seen extensive application in educational settings, contributing to advancements in students' academic performance across various subjects, such as science concepts (Fernández-Gutiérrez et al., 2020; Mohalik and Mohapatra, 2021; Lagura, 2022). It has also been instrumental in fostering linguistic and communication competence (Bilyalova, 2017) as well as language proficiency (Ariza and Sánchez, 2013), and has been found to positively correlate with students' engagement and self-directed learning (Rashid and Asghar, 2016). Moreover, ICT integration has been associated with increased student interest in attending classes (Shieh, 2012) and cultivating positive learning attitudes (Su, 2011). Also, students instructed using the ICT-integrated 5E learning model demonstrated significantly better higher-order thinking skills in biology compared to those taught solely through the 5E learning model (Shivam and Mohalik, 2022).

When considering the integration of ICT into the teaching of an abstract subject like mathematics in particular, research indicates that teachers may encounter challenges in incorporating technology into the teaching and learning processes. Key hurdles include a lack of knowledge on how to integrate ICT into lessons, insufficient training opportunities for ICT integration (Agyei and Voogt, 2011; Ifegbo et al., 2015; Aslan and Zhu, 2016; Niem et al., 2020), limited availability of resources, technical support, and financial constraints for maintenance and operational expenses (Mukuna, 2013). Other barriers include a lack of confidence or competence in using ICT (Aslan and Zhu, 2016), inadequate access to suitable software, infrequent use of telecommunication devices for student interaction, and a negative attitude toward ICT integration and resistance to innovation (Mukuna, 2013; Wanjala, 2016; Niem et al., 2020). Also, slow internet, frequent disconnections, and feeling anxious about using technology are some other challenges faced by pre-service teachers (Atmacasoy and Aksu, 2018). In OECD nations, mathematics teachers have access to both equipment and technical skills, yet encounter challenges in effectively integrating technology into their teaching methodologies (Ananiadou and Rizza, 2010). Although they utilize learning management systems (LMS) for administrative and educational functions, their training and practical experience in leveraging technology for pedagogical purposes within the classroom setting remains insufficient (Ananiadou and Rizza, 2010; Tran et al., 2020).

Despite these challenges, ICT has found widespread use in teaching mathematics. It has positively impacted students' achievement (Kumud, 2013; Pilli and Aksu, 2013; Hardman, 2019) through methodologies such as flipped classrooms (Bhagat et al., 2016), augmented reality-enhanced mathematics lessons (Estapa and Nadolny, 2015), and the utilization of handheld technologies (Tan and Tan, 2015). Additionally, ICT use has been associated with the development of learning motivation in mathematics (Estapa and Nadolny, 2015; Bhagat et al., 2016). ICT has facilitated learning processes and supported collaborative learning through various online teaching software applications. For instance, GeoGebra has been utilized for graphing in Calculus (Takači et al., 2015), while Graphing Calculator has been employed for teaching Probability (Tan and Tan, 2015). Mobile Augmented Reality apps have been effective in teaching the plotting of quadratic equations (Barraza Castillo et al., 2015) as well as algebra and geometry concepts (Chen, 2019), and in developing 3D thinking skills in geometry (İbili et al., 2020). Additionally, PowerPoint programs have been utilized for teaching concepts like surface area and volume (Kumud, 2013), while Frizbi Mathematics 4 has been employed for teaching multiplication and division of natural numbers and fractions (Pilli and Aksu, 2013). Moreover, ICT has enhanced the utility, self-efficacy, and compatibility of the flipped classroom strategy (Bhagat et al., 2016) in teaching Logic (Mohamed and Lamia, 2018), and has contributed to improved retention and fostered positive attitudes toward learning mathematics (Pilli and Aksu, 2013; Yusuf et al., 2014). Considering these various positive influences of ICT, researchers were enticed to explore its effectiveness in teacher education.

In the domain of ICT integration within pedagogy courses of pre-service teacher education, significant benefits have been observed. This includes benefits in developing lesson plans (Janssen and Lazonder, 2016; Varanasi et al., 2019), facilitating the computation of student results, and delivery of PowerPoint presentations (Niem et al., 2020). Notably, the efficacy of a web-based program named T.E.A.C.H. has been demonstrated in enhancing pre-service teachers' psychological and pedagogical competencies. This is evidenced by the cultivation of positive attitudes toward online teaching and learning, increased self-efficacy in online teaching formats, intentions to utilize technology for educational purposes, and the refinement of online pedagogical skills (Ho et al., 2023). Likewise, the use of web-based technology resources was positively associated with the achievement of pre-service teachers in their teacher education training (Garba et al., 2013). Additionally, a predominant reliance (90.9%) on improvised virtual laboratory experimentation has been observed among pre-service science teachers in their instructional practices (Bhukuvhani et al., 2010).

Regarding the integration of ICT into mathematics teacher education, the professional competencies of mathematics educators have been found to be enhanced through the utilization of the cloud service CoCalc as a teaching tool for mathematical disciplines (Popel, 2019). Wu et al. (2021) demonstrated that an online technology-enhanced teacher training environment, integrated with a visual learning design tool and learning analytics functions in STEM, effectively addresses practical challenges encountered by pre-service teachers in their teaching. Byrka et al. (2019) substantiated that a proficient level of ICT competence significantly enhances both the teaching and learning processes. It serves to facilitate teachers' professional development and aids in their adaptation to changes in educational technologies. Bozkurt and Koyunkaya (2022) delved into the development of prospective secondary mathematics teachers' planning and execution of technology-based mathematical tasks. They proposed that providing a conceptual foundation through dynamic geometry task analysis and instrumental orchestration frameworks contributes to enhancing these skills. On a related note, Prilop et al. (2020) explored the fostering of pre-service teachers' feedback competence during practicum experiences. They suggested that creating blended digital video-based feedback environments and enabling pre-service teachers to practice delivering feedback to their peers on their classroom performance can enhance this crucial aspect of teaching competency. ICT integration was also found effective in developing Technological Pedagogical Content Knowledge of pre-service mathematics teachers (da Silva Bueno and Niess, 2023). The integration of ICT in mathematics education equips mathematics teachers with comprehensive teaching methods that stimulate student learning, foster independent inquiry, and encourage active participation in the exploration of mathematical concepts and topics. Consequently, this approach facilitates a deeper comprehension of mathematical ideas among students (Baya'a and Daher, 2013).

Following an extensive review of extant literature, the researchers have drawn the conclusion that despite the well-documented significant impact of ICT integration in teaching and learning (Pilli and Aksu, 2013; Nihuka and Bussu, 2015; Srisawasdi et al., 2018; Saini and Abraham, 2019; Mohalik and Mohapatra, 2021), especially in mathematics instruction (Agyei and Voogt, 2011; Takači et al., 2015; Akkaya, 2016; Popel, 2019) and its substantial contribution to enhancing various aspects of teacher education (Bhukuvhani et al., 2010; Janssen and Lazonder, 2016; Varanasi et al., 2019; Niem et al., 2020; Ho et al., 2023), particularly in mathematics teacher education (Byrka et al., 2019; Popel, 2019; Prilop et al., 2020; Wu et al., 2021; Bozkurt and Koyunkaya, 2022; Samantray and Acharya, 2022), there exists a noticeable gap in studies addressing the effectiveness of ICT integration specifically focused on developing various dimensions of teaching competencies among pre-service teachers. Furthermore, there is a dearth of research addressing the effectiveness of ICT integration in cultivating teaching competencies among pre-service teachers, particularly those specializing in mathematics education.

In response to this gap in the literature, the researchers collaborated to investigate the effectiveness of ICT-integrated pedagogy in teacher education courses. This research is particularly tailored to the context of pre-service teacher education, with a specific emphasis on the teaching competencies of pre-service mathematics teachers in the educational landscape of Odisha. Thus, the primary aim of this investigation is to assess the efficacy of ICT-integrated pedagogy in enhancing the teaching competencies of pre-service teachers in mathematics, with a comparative analysis against the traditional lecture-based pedagogy.

2 Method and procedure

2.1 Sample and sampling technique

The sampling procedure (Figure 1) of the study centered on pre-service teachers ($N = 30$) enrolled in the 7th semester of the B.Sc., B.Ed. program at Fakir Mohan (Autonomous) College in Balasore district, Odisha. These pre-service teachers, specializing in mathematics as one of their pedagogy subjects, were purposefully

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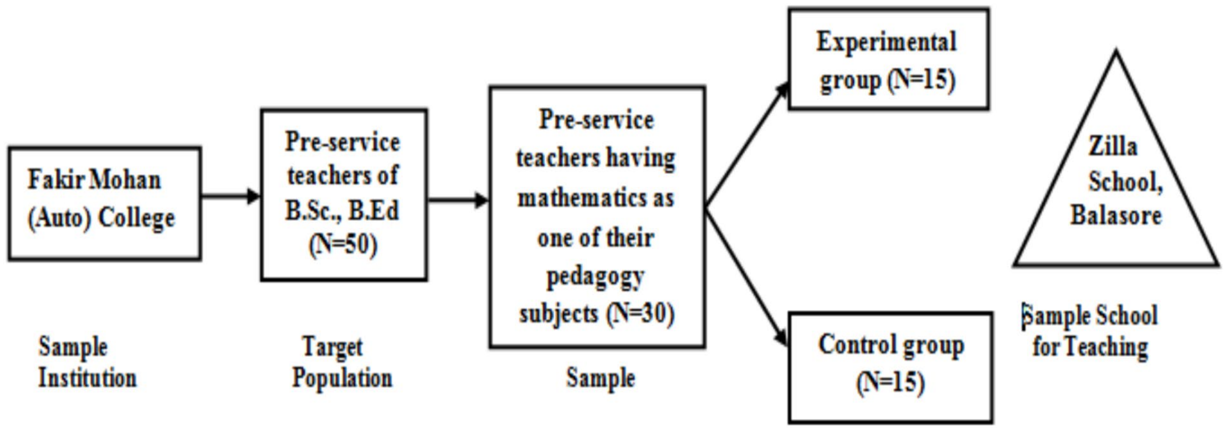

FIGURE 1
Sampling procedure.

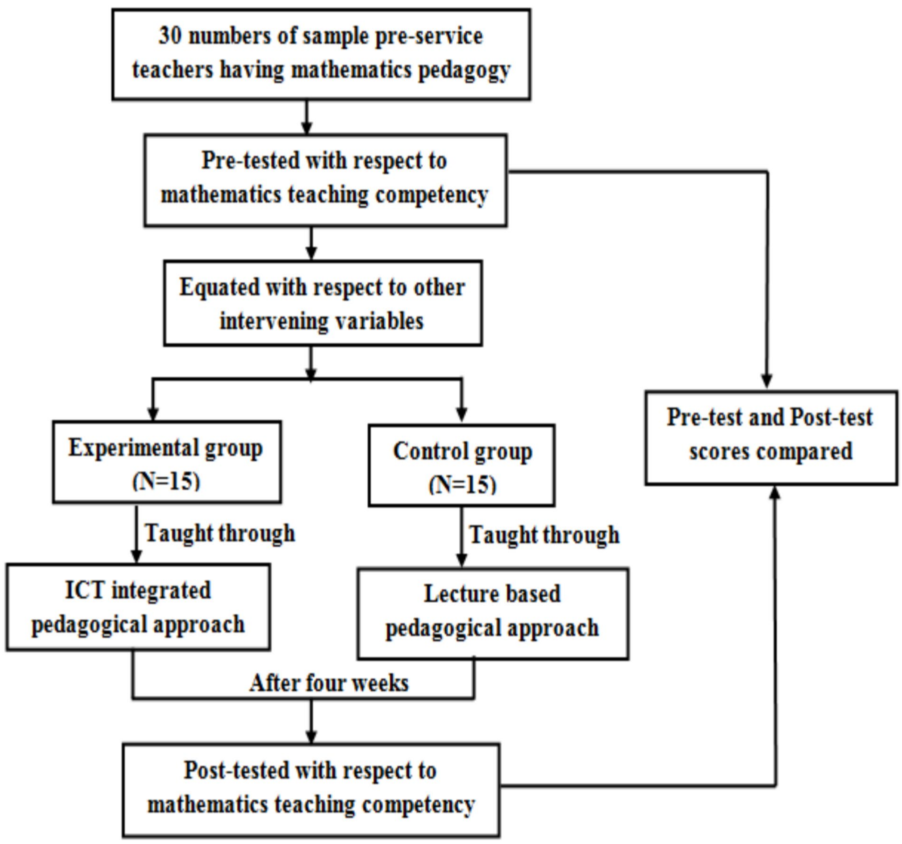

FIGURE 2
Design of the study.

chosen. Through random assignment, pre-service teachers were allocated to either the experimental or control groups, with each group consisting of 15 participants. To conduct the study, Zilla School in Balasore was finalized after careful deliberation and obtaining prior approval from the principal. The selection of the institution/university, participants, and the school (Zilla School, Balasore) aimed to maintain consistent experimental conditions.

2.2 Research design

The research design (Figure 2) incorporated a quasi-experimental method utilizing a pretest-posttest control group design. Two independent variables, namely 'ICT-integrated pedagogy in mathematics' and 'Traditional Lecture-based pedagogy,' were implemented as treatments, with the dependent variable being the teaching competence of pre-service teachers in mathematics. The research aimed to investigate the effects of both treatments on the teaching competence of pre-service teachers in mathematics. It was carried out in three successive phases namely, (i) the Pre-testing Phase, (ii) the Treatment phase, and, (iii) the Post-testing phase as described below;

2.2.1 Pre-testing phase

In the pre-testing phase the researchers constructed and standardized the 'Mathematics Teaching Competency Scale' (MTCS) to assess the teaching competence of pre-service mathematics teachers. Two separate instructional modules, ICT-integrated pedagogy, and traditional lecture-based pedagogy, were designed and validated with input from seven experts in the field. Pre-service teachers ($N = 30$) with mathematics as one of their pedagogy subjects were selected, and their teaching competency was pre-tested using the MTCS through observation and rating of three lessons per teacher. The average ratings were finally recorded for each pre-service teacher.

2.2.2 Treatment phase

The 30 pre-service mathematics teachers were divided into experimental and control groups, each comprising 15 teachers, with careful consideration to equate variables such as IQ, age, socio-economic status, and educational qualification. The experimental group was taught using ICT-integrated pedagogy, while the control group was taught using the traditional lecture-based pedagogy. The intervention continued for 4 weeks as outlined in the instructional modules.

2.2.3 Post-testing phase

After the four-week treatment period, each pre-service teacher underwent post-testing using the same MTCS tool and process as in the pre-testing phase. Precautions were taken to maintain consistent experimental conditions. The average ratings for each pre-service teacher were calculated and recorded for subsequent data analysis.

2.3 Research tools

The following two tools were used in the research:

2.3.1 Mathematics teaching competency scale (MTCS)

The MTCS was developed purposefully to measure pre-service teachers' teaching competency in mathematics both at the pre-testing and post-testing phases. The scale utilized a five-point Likert-type rating system, ranging from '1' representing 'very poor performance' to '5' indicating 'excellent performance'. The assessment of mathematics teaching competency was conducted through direct observation of pre-service teachers' mathematics teaching at the designated school. The scale comprised a total of 60 items distributed across eight different dimensions of mathematics teaching competencies. These dimensions included, (i) Instructional Objectives and Content Organization, (ii) Introduction, (iii) Presentation, (iv) Knowledge of Mathematics, Mathematical Language and Process, (v) Use of Teaching Learning Materials (TLMs) including ICT Tools, (vi) Management of Class Time and Learning environment, (vii) Motivation/Reinforcement, and (viii) Summarization and Evaluation. In addition to quantitative ratings, a provision was made for observers to provide special remarks, if any, regarding teaching competency. As a result, the maximum possible score for the scale was 300, while the minimum was 60.

After compiling a set of items across eight competency dimensions, the initial scale underwent expert validation. Based on feedback from seven field experts, certain items were revised, several dimensions were rephrased, and some items were eliminated, resulting in a final selection of 60 items distributed across eight dimensions. Subsequently, the draft scale was administered to a random sample of 10 pre-service teachers enrolled in the Teacher Education Department of Dharanidhar (Autonomous) College, located in Keonjhar district of Odisha, for pilot testing. The researcher observed and scored each pre-service teacher's teaching performance using the scale.

Content validity and concurrent validity were established by comparing the MTCS with the General Teaching Competency Scale (GTCS) developed by Passi and Lalitha (1994), as well as the Mathematics Teaching Competency Assessment Scale (MTCAS) developed by Kaushik (2011). The coefficient of correlation, found to be 0.75, indicated the validity of the developed scale.

The reliability of the final MTCS was determined using the test–retest method. The scale was administered twice to a sample of 10 pre-service teachers, with a four-week interval between administrations. The scores from the two administrations were then used to calculate the coefficient of correlation. The reliability coefficient (R) obtained for the overall scale was 0.86, indicating that the MTCS developed for pre-service teachers demonstrated high reliability.

2.3.2 Instructional tools

Two instructional modules were developed for mathematics pedagogy: the 'ICT-Integrated Mathematics Pedagogy' module for the experimental group and the 'Lecture-based Mathematics Pedagogy' module for the control group. The content of these modules underwent validation by seven experts from this field and was tailored to align with the secondary mathematics teacher education curriculum of Odisha. Emphasis was placed on mathematics teaching competencies, which were presented sequentially within the modules. Both modules had identical content and were designed to span 4 weeks, but they differed in instructional approach. These modules served as concise outlines detailing the various teaching competencies and skills essential for pre-service teachers to know and implement in their classroom instruction of mathematics. The experimental group received instruction through an ICT-integrated mode, while the control group received traditional lecture-based instruction employing the chalk-and-talk method.

2.4 Content of the instructional modules

The content outline for each instructional module was as follows:

Week 1 of the module encompassed pre-lesson activities, focusing on (i) identification of learning points, (ii) Bloom's taxonomy, (iii) formulation of instructional objectives, (iv) preparation and utilization of concept maps in teaching mathematics, (v) sequential organization of content and activities, and (vi) lesson planning based on the constructivist 5E Model of teaching.

Week 2 of the module focused on major teaching skills, including (i) assessing students' previous knowledge, (ii) skill of introducing a topic, (iii) skill of engaging students, (iv) skill of exploring content, (v) skill of presenting information, (vi) skill of reinforcement, (vii) skill of illustrating concepts with examples, (viii) skill of probing questioning techniques, and (ix) skill of effectively utilizing the blackboard.

Week 3 of the module addressed essential teaching skills, covering topics such as (i) skill of explanation, (ii) skill of preparation and utilization of TLMs, (iii) integration of ICT tools in mathematics instruction, (iv) skill of stimulus variation, (v) skill of students' response management, (vi) skill of summarization, (vii) skill of evaluation, and (viii) skill of classroom management time management, and resource management with a focus on inclusivity.

Week 4 of the module delved into additional teaching competencies and recent trends in mathematics instruction, covering topics such as (i) the nature of mathematics and mathematical processes, (ii) theories on children's mathematical learning, (iii) various methods and approaches to teaching mathematics, (iv) factors influencing students' mathematical learning, (iv) strategies for fostering mathematical language and thinking skills, and (v) approaches for addressing individual differences among students.

2.5 ICT-integrated mathematics pedagogy module

The ICT-Integrated Mathematics Pedagogy module was meticulously crafted to provide a comprehensive overview of the specific ICT tools to be utilized and their application in delivering instructional content. This module, tailored for the experimental group consisting of 15 pre-service teachers, was conducted entirely online, combining synchronous and asynchronous learning modalities. Participants accessed the course materials via the LMS platform, Google Classroom, using their registered email IDs for asynchronous learning. Additionally, synchronous weekend meetings were organized via Google Meet to facilitate face-to-face interactions. The interactive course module incorporated a variety of ICT tools, detailed as follows:

- Google Classroom served as the LMS for this module. All course materials and related activities were conducted asynchronously through this platform. Pre-service teachers were contacted via WhatsApp chat and were requested to enroll in the orientation using their email IDs.
- Google Meet was selected as the platform for synchronous weekend meetings to address participants' queries, and concerns, and facilitate direct interaction for obtaining feedback.
- The LUMI app served as an assessment tool, with the researcher designing the weekend assessment quiz through it. The quiz links were then posted on the LMS to facilitate simultaneous assessment of learning.
- ScreenPal, a screen recording software, was utilized to create lecture videos corresponding to the content of each week. Subsequently, these videos were posted on the LMS for access by participants.
- A-Z Screen Recorder was employed to record practical demonstration videos showcasing various teaching competencies. These videos depicted classroom teaching scenarios in secondary-grade mathematics, illustrating the application of different teaching skills.
- YouTube was utilized solely for uploading demo videos, enabling the sharing of video links through the LMS. This approach was adopted due to data limitations within the Google Classroom LMS. Additionally, links to existing YouTube videos relevant to the content were shared through the LMS for further reference.
- Microsoft Office applications, including MS Word, PDF, and MS PowerPoint, were utilized to develop interactive e-content featuring figures, diagrams, and sample lesson plans. These materials were integrated into the lecture videos for each week.

2.6 Traditional lecture-based mathematics pedagogy module

The Traditional Lecture-Based Mathematics Pedagogy Module was tailored to provide instructional content to the control group ($N = 15$) using a conventional lecture-based teaching approach. This module followed a similar structure and duration as the ICT-Integrated Mathematics Pedagogy Module, spanning 4 weeks. In contrast to the experimental group, the control group underwent traditional face-to-face teaching methods, devoid of online or technology-enhanced tools. The teaching methodology for the control group centered on direct, in-person lectures delivered through conventional chalk-and-talk methods. Emphasis was placed on verbal communication, concept explanation, and demonstration of teaching skills without the integration of online tools or any asynchronous components such as MS Word, MS Excel, MS PowerPoint, or PDF documents. The traditional lecture-based approach aimed to provide a basis for comparison to the experimental group's experience with ICT-integrated pedagogy.

2.7 Data analysis

The research utilized descriptive statistics and t-tests to analyze pre-test and post-test data. The mean scores of both the experimental and control groups, consisting of 30 pre-service teachers, were compared using SPSS version 20.

3 Results

3.1 Pre-test

The pre-test aimed to evaluate the baseline level of mathematics teaching competency among both the experimental and control groups before introducing any treatment. Each of the 30 pre-service teachers underwent three pre-tests on mathematics teaching

TABLE 1 Tests of normality.

Pre-test scores	Group	Shapiro–Wilk		
		Statistic	df	Sig.
	Experimental group	0.932	14	0.297
	Control group	0.953	14	0.574

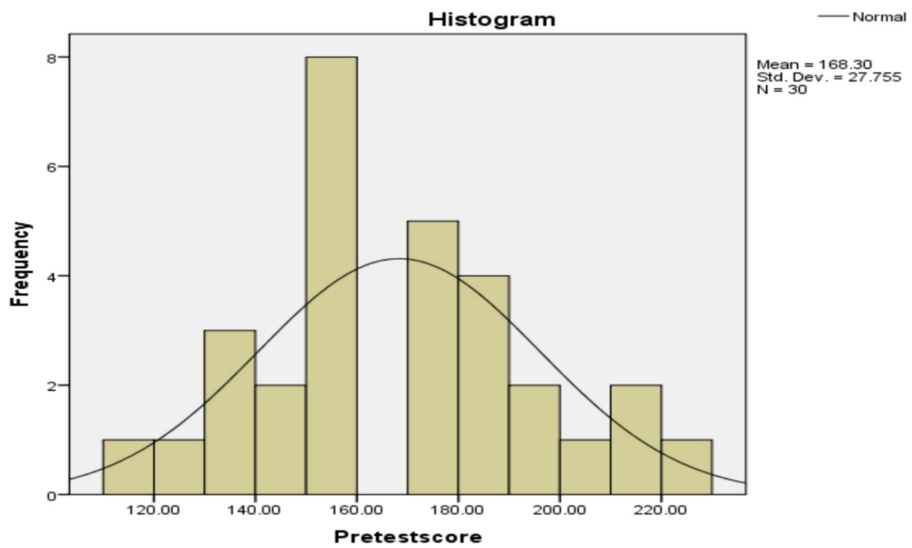

FIGURE 3
Normal probability curve of pre-test.

TABLE 2 Mean difference of mathematics teaching competency between experimental and control group pre-test scores.

Variable	Group	Mean	SD	*N*	df	*t*-value	Significance level
Mean mathematics teaching competency	Experimental group	168.33	28.23	15	28	0.006	$p = 0.995 > 0.05$
	Control group	168.26	28.25	15			

competency using the MTCS. The sum of scores found from each rating was standardized by taking its average value. The normality of pretest scores was assessed using the Shapiro–Wilk test of normality, considering the small sample size (<50). Subsequently, the pre-test scores of both the experimental and control groups were compared in terms of mathematics teaching competency using a *t*-test.

3.1.1 Normality of pre-test scores

The Shapiro–Wilk test (Table 1) was employed to assess the normality of the pre-test scores for both the experimental and control groups. Notably, for the experimental group, the test yielded a significance/*p*-value of 0.297, and for the control group, it resulted in a significance/*p*-value of 0.574. These findings indicated that the pre-test datasets for both groups exhibited normality, as the significance/*p*-values surpassed the conventional threshold of 0.05 ($p > 0.05$). This affirmation of normality was further substantiated by the visual examination of the Normal Probability Curve for the pre-test data (Figure 3), reinforcing the assertion that the data distributions closely approximate normality.

3.1.2 *T*-test comparison for pre-test

Table 2 presents the mean values and standard deviations of pre-service teachers' mathematics teaching competency scores for both the experimental and control groups at the pretest stage. The experimental group exhibited a mean score of $M = 168.33$ ($SD = 28.23$), while the control group displayed a mean score of $M = 168.26$ ($SD = 28.25$). The *p*-value for the pre-test, $p = 0.995$, surpassed the significance threshold of $\alpha = 0.05$. Consequently, the calculated *t*-value of $t(28) = 0.006$ was non-significant. Thus, there is no significant difference in the mean mathematics teaching competency scores between the experimental and control groups at the baseline stage.

3.2 Post-test

The post-test was conducted using the same tool after 4 weeks of continuous exposure to 'ICT-integrated Mathematics Pedagogy' and 'Traditional Lecture-Based Mathematics Pedagogy' for the experimental and control group pre-service teachers, respectively.

TABLE 3 Tests of normality.

Post-test scores	Group	Shapiro–Wilk		
		Statistic	df	Sig.
	Experimental group	0.940	14	0.384
	Control group	0.957	14	0.633

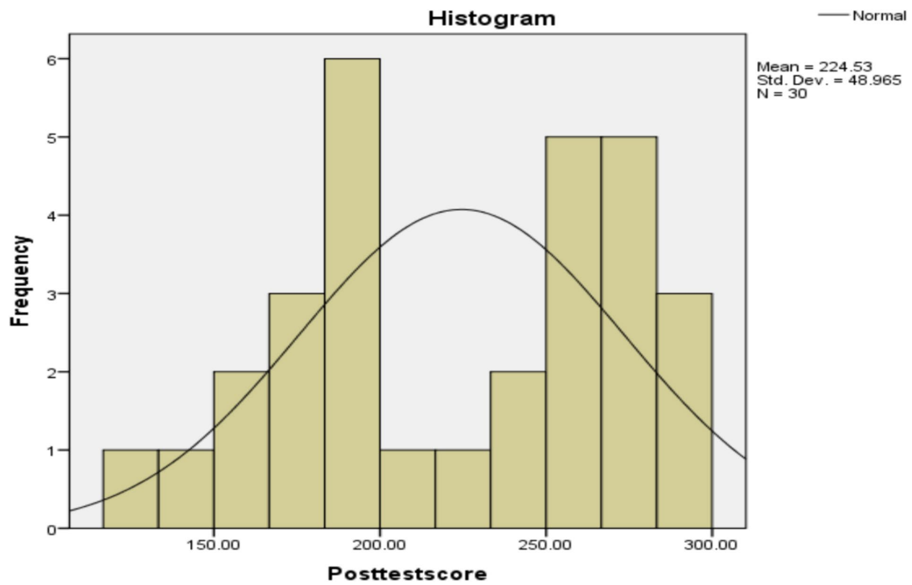

FIGURE 4
Normal probability curve of post-test.

TABLE 4 Differences in the mean scores of the post-test of the experimental group and control group.

Variable	Group	Mean	SD	*N*	df	*t*-value	Significance level
Mean mathematics teaching competency	Experimental group	268.33	15.55	15	28	11.60	$p = 0.000 < 0.05$
	Control group	180.73	24.76	15			

The purpose was to assess the mean score differences between the groups in mathematics teaching competency at the end-line stage and compare those scores with the pre-test scores. The same procedure was used for rating pre-service teachers' mathematics teaching competency, testing the normality of the scores, and comparing group differences as conducted in the pre-test.

3.2.1 Normality of post-test scores

The Shapiro–Wilk test (Table 3) was conducted to assess the normality of the post-test scores for both the experimental and control groups. For the experimental group, the test yielded a significance/p-value of 0.384, and for the control group, it yielded a significance/p-value of 0.633. Notably, these significance/p-values exceeded the conventional threshold of 0.05 ($p > 0.05$), suggesting that both datasets approximate normal distributions. This conclusion was further supported by visual inspection of the Normal Probability Curve for the post-test data (Figure 4), reinforcing the assertion that the data aligns closely with the normal distribution.

3.2.2 *T*-test comparison for post-test

Table 4 presents the mean values and standard deviations of pre-service teachers' mathematics teaching competency scores for both the experimental and control groups at the post-test stage. The experimental group exhibited a mean score of $M = 268.33$ ($SD = 15.55$), while the control group displayed a mean score of $M = 180.73$ ($SD = 24.76$). The significance value for the post-test, $p < 0.05$, was 0.000, indicating a highly significant difference between the groups. The calculated t-value of $t(28) = 11.60$ exceeded the critical value for a significance level of $\alpha = 0.05$, suggesting a significant difference in the mean mathematics teaching competency scores between the experimental and control groups at the end-line stage. In other words, the mean mathematics teaching competency scores of experimental and control group pre-service teachers differ significantly at the end-line stage. Hence, it can be concluded that pre-service teachers in the experimental group, who were taught using ICT-integrated mathematics pedagogy, demonstrated significantly higher proficiency in mathematics teaching competence compared to

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their counterparts in the control group, who were taught using traditional lecture-based mathematics pedagogy. Figure 5 illustrates the comparison of mean teaching competency between the experimental and control groups.

4 Discussion and conclusion

The study unequivocally demonstrates that the implementation of ICT-integrated pedagogy among pre-service mathematics teachers significantly contributes to the enhancement of their teaching competency in mathematics. In stark contrast, the traditional lecture-based pedagogy appears somewhat insufficient in fostering remarkable improvements in their teaching competencies. This aligns with prior studies emphasizing the highly positive impact of ICT on teaching and learning in general (Pilli and Aksu, 2013; Nihuka and Bussu, 2015; Srisawasdi et al., 2018; Saini and Abraham, 2019; Mohalik and Mohapatra, 2021) and specifically in mathematics education (Agyei and Voogt, 2011; Takači et al., 2015; Akkaya, 2016; Popel, 2019; Samantray and Acharya, 2022). This study's findings align with prior research by Janssen and Lazonder (2016) and Varanasi et al. (2019), who observed that technology integration aids in enhancing teachers' lesson-planning skills. Additionally, Popel (2019) demonstrated that the professional competencies of mathematics educators can be augmented through the utilization of cloud services like CoCalc for teaching mathematical disciplines, as well as for computing student results and delivering presentations using PowerPoint (Niem et al., 2020). Similarly, Nandhakumar and Govindarajan (2022) reported a positive impact of digital pedagogy on teaching competencies in Physical Science, further reinforcing the benefits of technology integration. The observed positive outcomes documented in the studies could be attributed to the ICT-integrated pedagogy's role in enhancing pre-service teachers' teaching competencies. This pedagogy facilitates a practical demonstration of competencies through various multimedia elements such as images, text, audio, video, simulation, and animation. Consequently, pre-service teachers are better equipped to perceive the feasibility of different competence parameters in authentic classroom settings.

Despite the acknowledged challenges associated with integrating ICT into educational settings (Ananiadou and Rizza, 2010; Agyei and Voogt, 2011; Mukuna, 2013; Ifegbo et al., 2015; Wanjala, 2016; Niem et al., 2020), its undeniable efficacy and positive impact on teaching and learning cannot be ignored (Bhukuvhani et al., 2010; Janssen and Lazonder, 2016; Sahoo, 2019). Recognizing the potential of ICT, the Government of Odisha has invested substantially in reshaping the secondary school structure through its 5 T initiative (Teamwork, Technology, Transparency, Transformation, and Time limit). Consequently, secondary teacher education institutions in the state must consider adopting a similar approach to bolster the teaching strategies of their pre-service teachers. Hence, a major strength of this study lies in its provision of an alternative approach to enhancing the teaching competencies of pre-service teachers, a perspective that has yet to be thoroughly explored in existing literature.

This study underscores the pressing need for pedagogical institutions/teacher-education universities/colleges/institutions not to lag behind in educational advancements but rather to equip future teachers with the necessary skills to navigate the challenges of the 21st-century work culture. The findings suggest a growing demand for a competency-based curriculum in teacher education, as teachers' professional competency plays a pivotal role in influencing students' learning performance (Kunter et al., 2013; Jentsch, and König, 2022). In the context of Odisha, these findings hold implications for Teacher Education Institutions and Teacher Educators, urging them to prioritize the preparation of skillful and competent teachers, especially at the pre-service level. This proactive approach is vital for ensuring that teachers can effectively fulfill their future roles in this noble profession within the evolving educational landscape of the state.

The findings of this study underscore critical considerations with significant educational implications for curriculum planners, policymakers, institutional leaders, teacher educators, and practitioners. Particularly pertinent to educational policies in Odisha is the emphasis on substantial investments in ICT as part of

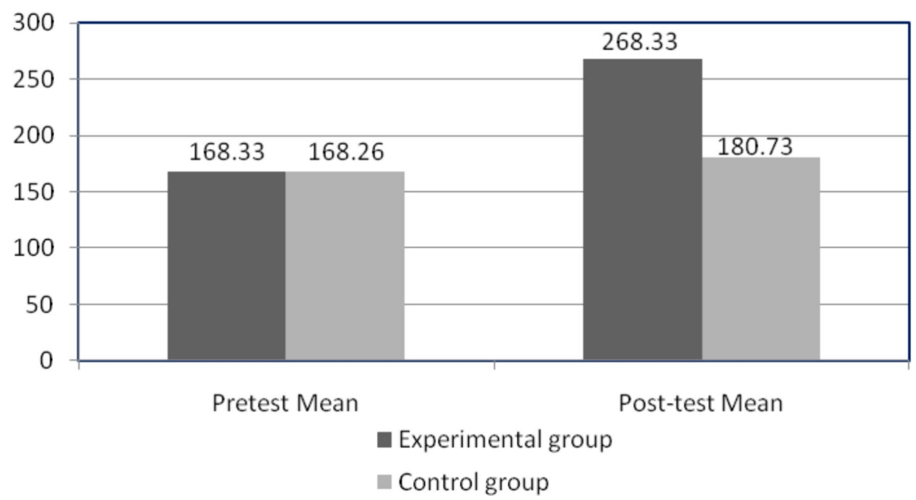

FIGURE 5
Mean comparison of teaching competency between experimental and control group.

the 5 T initiative, signaling a dedicated effort toward educational reform. The study accentuates the pressing need for teacher education institutions to adapt to educational progressions, advocating for a curriculum rooted in competencies to adequately equip future educators for the demands of contemporary work environments. The Government of Odisha's commitment to ICT integration sets a progressive trajectory for educational advancement, prompting teacher education institutions and educators in the region to prioritize the cultivation of proficient and adept teachers who play a pivotal role in shaping students' academic achievements. Furthermore, this research offers valuable insights applicable beyond regional boundaries, advocating for global educational stakeholders to embrace ICT integration within teacher education programs to effectively address the evolving dynamics of modern education. In navigating the intricacies of the digital era, the adoption of innovative pedagogical approaches becomes imperative to foster a cohort of educators capable of adeptly navigating the multifaceted challenges inherent in our dynamic educational landscape.

The study is not without its limitations. Primarily, it focused solely on secondary pre-service teachers, thereby constraining the applicability of its findings to elementary pre-service teachers. To achieve a more comprehensive understanding of the impact of ICT integration, future research endeavors could explore its effects on elementary pre-service teachers as well. Additionally, the study employed a quasi-experimental design, inherently limited in its ability to control confounding variables and ensure experimental validity. Enhancing experimental validity could be achieved through the adoption of a randomized controlled trial design in subsequent research endeavors. Furthermore, while the study integrated certain ICT tools into teaching practices, it did not encompass the full spectrum of evolving technologies available. Future investigations could incorporate a wider array of emerging ICT tools to assess their influence on teaching competence. Moreover, the study's sample size was relatively small, derived from a single institution, thus impeding the generalizability of its findings. To address this limitation, future studies could involve larger and more diverse samples to enhance the generalizability of results. Also, qualitative inquiries could be conducted to elucidate the relationship between the application of ICT-integrated pedagogy and various parameters of pre-service teachers' teaching competence in mathematics. Such qualitative studies could extend to subjects beyond mathematics, providing a more comprehensive understanding of ICT's impact on teaching competence across diverse educational domains.

In summary, this study highlights the transformative potential of ICT-integrated pedagogy in enhancing the teaching competence of pre-service mathematics teachers, demonstrating its superiority over traditional lecture-based methods. These findings resonate with existing literature emphasizing the positive impact of ICT on education, particularly in the realm of teacher training. However, further research is warranted to delve deeper into each of the eight dimensions used to measure teaching competence, providing a more thorough and nuanced analysis of the efficacy of ICT integration in pedagogical practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Fakir Mohan University Balasore. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. RB: Methodology, Writing – original draft, Writing – review & editing. AA: Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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