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Effectiveness of ICT Integrated Pedagogy on Pre-Service Teachers' Teaching Competence in Mathematics: A Critical Review

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Abstract:- In this era of technological revolution, our society has been witnessing transformations in almost every aspect of human life. It therefore, has potent impact on education and on classroom teaching-learning in particular. The evolution of Information and Communication Technology (ICT) has brought a radical change in the entire scenario of classroom teaching-learning. The inclusion of ICT in teaching-learning process impulses the learners to be tech-savvy, the teachers to be techno-competent and the classrooms to be technology enabled. Thus, it is the demand of time that the future teachers are trained to be competent enough in techno-pedagogy so as to meet their future roles according to the needs of learners. In this context, the present study aimed to provide a critical review of the research studies those identified the effectiveness of ICT integrated pedagogy in education with special reference to pre-service teacher education and teaching mathematics. A total of 70 qualified recent studies were included in this meta-analysis. The findings suggest ICT integration generally produced a positive effect, though moderate in comparison to the traditional approaches and that was dependent on the type of technology used and subject to be taught.

Keywords:- *Information and Communication Technology (ICT), ICT integrated pedagogy, Pre-service teachers, Teaching competence, Teaching competence in Mathematics.*

I. INTRODUCTION

The crucial role of teachers in the process of nation building has always been truly recognized as noble and pious. In this profession, teachers have to come across many challenges and successes from time to time while dealing with young minds during classroom teaching. When we talk about integration of technologies in the classroom teaching especially information and communication technologies, which include an extensive variety of tools/resources, there the question arises which technology will benefit student's learning and how effectively it can be used by a teacher keeping aside its drawbacks. How teachers' teaching competence can be enhanced through techno-pedagogy? How far it is effective over conventional approaches of teaching? For a subject like mathematics, is the technological integration to pedagogy will be justified? How far our pre-service teachers are ready and competent to adopt such innovation and bring productivity in their instructional practices? To get satisfactory answers to these questions and to have a clear picture of the current status of technology integration to pedagogy to pre-service teacher education, the researcher has critically reviewed the most recent studies from this field conducted in India and abroad from 2010 to 2022 and investigated the effectiveness of pedagogical integration of ICT.

II. METHODOLOGY

This study is a systematic review of a broad range of evidence based studies which includes a total of 70 studies from the field of effectiveness of ICT integrated pedagogy with special reference to pre-service teacher education and mathematics teaching competence. The reviewed studies include dissertations, theses and published papers including 2 review papers. The papers were retrieved from ERIC, EBSCOHOST, Elsevier, JSTOR, Google Scholar, SAGE full-text collection with help of University library open resources. The related studies from the field were then critically analyzed and investigated to get the answers to the following questions.

- In what way ICT integrated pedagogy impact upon teaching-learning?
- How ICT integrated pedagogy impact on teaching-learning of mathematics?
- In what way the ICT integrated pedagogy affect pre-service teachers' teaching competence and on mathematics teaching competence in particular?

A. In what way ICT integrated pedagogy impact upon teaching-learning?

Integration of ICT (Information and Communication Technology) into teaching-learning process affects the style of teaching as well as learning to a greater extent but the way it brings pedagogical change is rather very complex. As ICT comes with an array of tools/resources, its effect also depends on the type of technology used and the subject of teaching for which ICT is to be integrated **(Fernandez, G. et.al., 2020)**. It is concluded, when **Fernandez, et.al., (2020)** compared the impact of ICT on secondary students' outcomes across three subjects mathematics, reading and science, that ICT has a positive effect on outcomes in science but has no significant effects on that of mathematics and reading. **Bai, et.al, (2016)** integrated ICT to pedagogy of teaching English to grade-V students to improve their English learning, they found it effective in improving students' test scores and a similar effect on students with high and low initial levels of English competency. Similarly,

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Bilyalova, (2017) got similar results on the study of ICT usage in teaching foreign languages on students' achievement in reading comprehension and in grammar skills and also found it increased communicative competence, motivated for learning and promoted cognitive activity and independent work of students.

However, ICT integrated pedagogy also has a significant impact on learning performance of students in science subjects. ICT integration into chemistry teaching encouraged students to get a meaningful understanding of the chemistry concepts, process skills and promoted a positive attitude toward chemistry learning **(Su, 2011)**. Likewise, teaching of physics through Technology-Enabled Active Learning (TEAL) resulted into students' high scores in achievement test along with the encouragement to attend physics classes and active participation in extracurricular science activities and made teachers more enthusiastic and confident in helping students for strengthening physics concepts **(Shieh, 2012).** On contrary active participation of students decreased in ICT integrated classes but students' achievement increased through computer-based teaching strategies if students' awareness in ICT use and communication is enhanced **(Comi, 2017)**. In fact, technology use has a strong positive correlation with students' engagement and self-directed learning directly but no direct significant correlation between technology use and academic performance. Rather, the academic performance is enhanced indirectly by technology through enhancement in self-directed learning **(Rashid & Asghar, 2016)**. There are positive effects of ICT integrated pedagogy in teaching science at upper primary level on better conceptual understanding and achievement of learning outcomes in the subject **(Mohalik, et. al, 2021)**.

Types of technologies used are also the determining factors of its effectiveness. **Bilyalova, (2017)** found that PowerPoint presentation, correspondence by e-mail, training programs on CD-ROM and inclusion of internet resources in teaching are the most effective types of ICT for developing foreign language competence of students. Clicker Assessment and Feedback (CAF) technologies had a positive impact on students' engagement and learning. **Han & Finkelstein (2013)** reported that more appropriately the CAF developed and used by the professors for formative assessments, more effective was the students' engagement and learning. Teaching through the educational application softwares like 'Frizbi Mathematics 4' **(Pilli & Aksu, 2013)**, GeoGebra **(Takaci, et.al., 2015)**, and Graphing calculator(GC) **(Tan & Tan, 2015)** had a tremendous impact on students' achievement in mathematics. Likewise, integration of 'Kodu Game Lab' **(Gulsah & Alev, 2016)** and virtual laboratory experimentation **(Bhukuvhani et.al., 2010)** in science teaching contributed towards effective teaching. However, the application of mobile Augmented Reality (AR) **(Castillo et.al, 2015, Chen, 2019, Ibili et.al, 2020)** and Flipped classroom techniques **(Bhagat et.al, 2016, Mohamed & Lamia, 2018)** made learning mathematics easier and effective. **Varanasi, Kizilcec & Dell (2019**) incorporated a teacher-focused mobile technology intervention to the teachers in low-income government schools that caused teachers to reconfigure their work practices including lesson planning, classroom teaching practices, bureaucratic work processes and post-teaching feedback mechanisms.

B. How ICT integrated pedagogy impact upon teaching-learning of mathematics?

Integrating technology to teaching-learning of an abstract subject like mathematics is itself a challenge for teachers. Some of the major challenges identified as- lack of knowledge about ICT integration into lessons, lack of training opportunities for ICT integration **(Agyei & Voogt, 2011, Ifegbo et.al, 2015, Niem, 2020),** lack of resources, technical support and fund for maintenance & other operating expenses **(Mukuna, 2013)**, inaccessible to appropriate software, low self confidence & competency in using ICT, rare use telecommunication devices such as cable, satellite, fax-machine, etc. to interact with students **(Wanjala, 2016, Niem, 2020)** and negative attitude of teachers towards ICT integration and resistance to embrace innovation **(Mukuna, 2013)**.

In spite of the challenges**,** most of them utilize the benefits of technology in writing lesson plans **(Janssen & Lazonder, 2016)**, in computing students' results and in teaching the mathematics lessons through power point presentations **(Niem, 2020)**. Teaching of mathematics through the educational software like 'Frizbi Mathematics 4' found helpful in increasing 4th grade students' achievement scores in the concepts like Multiplication of Natural Numbers, Division of Natural Numbers and Fractions **(Pilli & Aksu, 2013)** where as the integration of GeoGebra application software in a computer supported collaborative learning environment found helpful in enhancing students' learning achievement in examining functions and drawing their graphs **(Takaci, et. al, 2015).** Similarly, teaching of Probability concepts by using graphing calculator (GC) and the GC instructional worksheets as teaching- learning tool, **Tan & Tan (2015)** reported a significant improvement in achievement scores of students of all levels (high, average and low) in Probability, especially low achievers were more benefitted. Achievement scores of secondary level students in Mathematics also improved through adopting ICT integrated approach in teaching **(Kumud, 2013).**

Besides this, use of mobile augmented reality (AR) apps in teaching algebra and geometry motivated learners with different levels of mathematics anxiety, especially the high-anxiety learners did better with higher confidence and were satisfied with the ease of use, usefulness, playfulness, and benefit from exploration and hands-on experiences **(Chen, 2019)**. Likewise, Augmented Reality (AR) supported geometry teaching found effective in developing students' 3D thinking skills, ability to recognize and create 3D shapes **(Ibili et.al, 2020)** and also proved to be a valuable complimentary and supportive teaching tool for topics that need contextual learning experience and multipoint visualization, such as 'quadratic equations' **(Castillo, et.al, 2015)**. Moreover, adoption of a Computer Mediated Systems Teaching Approach (CMSTA), in teaching mathematics to engineering students' fostered positive attitude towards mathematics learning **(Yusuf, et.al, 2014).**

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Flipped classroom techniques in teaching also had a positive impact on learner's learning achievement in mathematics (Trigonometry concepts) and motivation to learners belonging to different achievement levels **(Bhagat et. al, 2016)**. Flipped classroom learning environment found useful, easy to learn, compatible, enhance social ties through students' satisfaction, develops self-efficacy and positive attitude and intention towards continuing learning mathematics through it **(Mohamed & Lamia, 2018).**

C. In what way the ICT integrated pedagogy affect pre-service teachers' teaching competence and on mathematics teaching competence in particular?

Technologies solely have no significant impact on student's achievement **(Hardman, 2019)**, rather its effectiveness depends on the actual pedagogical practice that teachers adopts **(Hardman, 2019)** and on their ability to integrate ICT into their teaching process **(Comi, 2017)**. More often, lack of infrastructural facilities, lack of basic technical support **(Kihoza, Zlotnikova, Bada & Kalegele, 2016, Murithi & Yoo, 2021)**, poor network connection, limited time and accessibility and lack of effective training **(Ghavifek, Kunjappan, Ramasamy, & Anthony, 2015)** were the major drawbacks to ICT integration in teacher education courses. Somewhere, lack of competencies on pedagogical application and lack of ICT skills in pre-service teachers was hindering the integration of ICT in their teaching practices (**Aslan & Zhu, 2015, Ghavifek, Kunjappan, Ramasamy, & Anthony, 2015, Kihoza, Zlotnikova, Bada & Kalegele, 2016, Murithi & Yoo, 2021, Baruah & Mohalik, 2022).** So, professional development of teachers in ICT pedagogy and more opportunities for teachers to participate in ICT-based seminars and trainings is essential to gather the knowledge and skills about putting ICT tools into practice **(Fox, Diezmann, Lamb, 2016, Wanjala & Martin**, **2016, Aslan & Zhu, 2017, Niem, 2020, Baruah & Mohalik, 2022)**. Use of digital educational resources (DER) by the teachers in schools was largely dependent on both teacher- and school-level ICT trainings and its duration **(Wu, et.al, 2022).**

Moreover, mathematics teachers do not put emphasis on integrating ICT in mathematics teaching **(Agyei & Voogt, 2011)** and about 90.9% of pre-service science teachers use improvised virtual laboratory experimentation in science teaching while rest 9.1% of them did not use the technology in their teaching despite of knowing the value and benefits of virtual experiments **(Bhukuvhani et.al., 2010)**. In OECD countries, the student teachers have access to equipment and possess technical skills but were not competent in including it into pedagogical process. They used Learning Management Systems (LMS) for their administrative and learning needs but the training and experience they got on pedagogical use of technology in classroom was insufficient **(Ananiadou & Rizza**, **2010)**. On the other hand, teacher educators' were either lack time for full exploration of ICT applications in pedagogy because of information overload, excessive bureaucracy and a plethora of externally imposed initiatives in education **(Ananiadou & Rizza**, **2010)** or their adoption level of current educational technologies (CETs) was at low end or late adopters **(Ifegbo et.al, 2015).** In most of the Teacher Education Institutions (TEIs), Teacher Educators found using ICT sometimes in teaching-learning, assessment and for their professional development whereas majority of trainee teachers found not applying it during their teaching internship **(Baruah & Mohalik, 2022).**

However, Pre-service teachers' willingness to incorporate ICT into classroom teaching had a close dependency on their personality traits and psychological characteristics **(Kounenou et al, 2015)** whereas **Valtonen, et.al, (2015)** established no statistical relation between learning with ICT in pedagogically meaningful ways and the pre-service teachers' attitudes and behavioural intentions to integrate ICT in teaching and learning but with the self-efficacy and other areas of TPB(Theory of planned behavior). But the factors such as motivation, reasons to use technology in the course and level of challenge perceived had a great impact on student teachers' engagement with technology however; gender, technical ability and time spent on technology had no influence **(Cakir, 2013)** but **Ghavifek, Kunjappan, Ramasamy, & Anthony (2015)** proved that the male teachers' use of ICT tools in the classroom is higher in comparison to that of female teachers and also teachers in their 40s perceived higher ICT usefulness than those in their 30s **(Murithi & Yoo, 2021)**. Likewise, **Sindhwani, (2019)** found that techno pedagogical competency of male teachers overpowers that of female teachers, that of Science teachers was superior to Arts teachers and also that of less experienced teachers had much better in comparison to more experience teachers. On contrary, **Anand (2019)** revealed that all the faculty members have above average Techno-pedagogical competency and there was no significant demarcation between male and female or science and social science faculties with respect to their Techno-Pedagogical competency. In spite of existing obstacles as-slow internet access, connection failure and anxiety of using ICT, blended learning approach had positive impact on academic achievement and attitude of pre-service teachers in providing various materials, receiving prompt feedback and tracking progress **(Atmacasoy & Aksu, 2018)**.

Besides all, pre-service teachers' readiness to accept change or technology acceptance also had impact on their pedagogical ICT integration (**Kihoza, Zlotnikova, Bada & Kalegele, 2016).** Student teaching experiences of pre-service teachers' was suggested to bring their readiness for technology integration in teaching **(Sun, et.al, 2017)**. The ICT training method for teachers including guided sessions, training materials presenting authentic pedagogical examples and try-outs in the classroom also encouraged the less-experienced teachers to try new practices with ICT in teaching but they designed less coherent tasks and weaker support for pupils' collaboration, knowledge construction and meta-cognition than their more-experienced colleagues **(Lakkala & Ilomaki, 2015).** Such trainings given by combining technology, pedagogy and content knowledge to pre-service teachers' on mathematics teaching could bring positive changes in their perceptions regarding the use of technology and technology integration into teaching **(Akkaya, 2016). Janssen & Lazonder (2016)** proved that

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an integrated approach followed for creating technology-infused lesson plans found effective for pre-service teachers in having more pedagogical and content-related justifications and developing higher quality lesson plans however, the technology integration was of low quality. Similarly, integration of Kodu Game Lab (Microsoft) with MAGDAIRE (Modeled Analysis, Guided Development, Articulated Implementation and Reflected Evaluation) framework into learning process of pre-service science teachers had enhanced their Technical Proficiency of Kodu software and other digital game based learning in science **(Gulsah & Alev, 2016)**.

There were positive impacts of TPACK and SAMR models on pre-service teachers' technology use in their planning and redesigning of learning tasks in comparison to that before (**Kihoza, Zlotnikova, Bada & Kalegele, 2016)**. **Jimoyiannis** (**2010)** designed a TPASK (Technological Pedagogical Science Knowledge) model based on the integrated framework of TPACK model for professional development through technology integration which was proved beneficial for science teachers in acquiring meaningful TPASK knowledge and increased willingness to adopt and integrate this framework into science classrooms. In a similar way **Jang & Chen (2010)** employed a transformative model of integrating technology and peer coaching and found that the model was helpful to pre-service science teachers in integrating subject-matter knowledge into science lessons and enhancing their TPACK (technological pedagogical and content knowledge). Pre-service teachers´ competencies to integrate technologies in future classroom teaching practices could be developed when they have exposure to ICT tools such as Web 2.0 tools, blogs, podcasts and Google Sites in creating digital artifacts for classroom use **(Coutinho, 2012). Garba, et.al, (2013)** exposed pre-service teachers to ICT-based instruction by integrating web-based resources, smart board and power point for pedagogical practices of social studies and found it effective for developing their TPACK in social studies. Significant changes in technology-related components of TPACK of pre-service teachers' perceived knowledge and skills of integrating technology in teaching was observed by **Kafyulilo et.al (2015)** when they adopted TPACK framework for microteaching, hands-on training, collaborative lesson designing and peer reflections.

Han, et.al, (2013) showed an increase in TPACK scores of pre-service teachers through case-based learning on knowledge integration related to teaching with technologies but content-relevant knowledge for technology integration was not developed through it. But a technology-integrated pedagogy called Mobile Laboratory Learning in Science (MLLS) had given a better level of technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK to pre-service science teachers **(Srisawasdi, et.al, 2018)**. Also the technology based teacher education curriculum was assessed to be effective by evaluating Techno Pedagogy Integration Skill (TPIS) in line with TPACK with respect to Concept attainment and skill acquisition of pre service teachers **(Nayar & Akmar, 2020)**. Similarly, the incorporation of subject-specific TPACK modules in different subjects found effective on pre-service teachers' technology-related self-efficacy, their perceived support for technology integration and also in acquiring more TPACK **(Lachner et. al, 2021).** It was also noticed that that pre-service teachers have a strong knowledge in all the seven elements of TPACK but the application of TPACK was significantly controlled by TPK and TCK. In between TPK and TCK, TPK had a stronger impact on the TPACK applications of the pre-service teachers **(Santos & Castro, 2021).** Thus, Pre-service teachers had a good knowledge of ICT tools and its significances and acknowledged its multiple advantages when teachers integrating ICT in the classroom **(Kelani, 2022)** but in order to develop pre-service teachers' knowledge and skills to integrate technology in teaching and learning or TPACK, technology-infused courses were important **(Admiraal, et.al, 2017).** Pedagogical knowledge, ICT-related courses and perceived ICT competence of pre-service teachers accounted for 17% of the integration of ICT into their teaching practices **(Aslan & Zhu, 2017).** Pre-service teachers' teaching competency in Physical science had remarkably improved on exposure to digital pedagogy with special reference to 5E model of Constructivism **(Nandhakumar & Govindarajan, 2022).**

In particular, the integration of ICT in teaching-learning mathematics had both positive and negative impact on students' achievement in mathematics and pedagogy at elementary school level **(Hardman, 2019).** The professional development programme on ICT integration in teaching and learning of Mathematics in secondary schools helped 5.2% of the teachers only in acquiring technological and technological-pedagogical knowledge but not the content **(Nihuka & Bussu, 2015)** although it made teachers optimistic for future use of ICT in improving their Mathematics teaching. But in spite of availability and access to technologies such as learning management systems and ability of pre-service mathematics teachers to use ICT tools, ICT integration in mathematics teaching was found ineffective **(Tran, Phan, Le & Nguyen, 2020).** Mathematics teachers' integrate ICT into their classroom teaching only when they found it beneficial in increasing productivity and social influence otherwise, they did not necessarily use ICT **(Graham, Stols & Kapp, 2020).** Also the insufficiency in pre-service teachers ' TPACK development in mathematics teaching and learning held up them to receive a good understanding and perception regarding technology use in the training of mathematics teaching **(Marban & Sintema, 2020).**

On contrary, Professional Development Schools (PDS) adopting new technological innovations were served as boost for the professional development of pre-service mathematics teachers when they practiced teaching in these training schools **(Wajeeh, et.al, 2018)**. However, Pre-service teachers' learning achievement and engagement levels in pedagogy of mathematics course improved significantly through Facebook-based instructional approach **(Saini & Abraham, 2019).** Teachers had a little self-efficacy to implement ICT into actual teaching but they thought to be at least adequately proficient in ICT integration in teaching mathematics regardless the actual

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implementation in classrooms **(Wei, 2021).** A methodical training to pre-service teachers' on teaching professional and practical aspects of mathematics found effective in developing their ICT competency and thereby preparing competent mathematics teachers using ICT tools **(Lovianova, et,al 2021).** Hence, a model combined with contextual knowledge and technological knowledge of Pre-service teachers TPACK could be helpful in predicting their attitudes towards ICT integration in mathematics teaching **(Marban & Sintema, 2020)**.

III. DISCUSSION AND CONCLUSION

The integration of ICT tools to classroom teaching though poses many challenges for teachers and learners, its effectiveness cannot be undermined. It is found ICT integration into Mathematics teaching-learning in particular, fosters cognitive ability of the students, promotes engagement in learning, enhances conceptual understanding and moreover develops students' interest and positive attitude towards learning. Because, integration of ICT tools into classroom teaching supports learning theory by developing connections between the verbal stimuli to its visual representation **(Su, 2011)** and hence, makes learning effective and permanent. Thus, it is evident that future of teacher education has to rely on technology inclusion and its integration into pedagogy. The effective integration of ICT in subject like mathematics is been realized as challenge for practitioners as well as for researchers **(Marban & Sintema, 2020)**. Among all, lack of teachers' professional development opportunities is identified as the major barrier to ICT integration into classroom teaching **(Fox, Diezmann, Lamb, 2016).** Because technologies on its own have no significant impact **(Hardman, 2019)** rather it is the Teacher whose techno-pedagogical competency decides the effective use of ICT in the classroom. Therefore, Pre-service teachers should be professionally prepared to acquire techno-pedagogical competency so as to integrate ICT into their future classroom teaching practices **(Wanjala, 2016, Aslan & Zhu, 2017**) and given more opportunities to involve in ICT-based seminars and workshops (**Niem, 2020)**. However, the challenges related to necessary infrastructure for ICT infusion, technical staff support, fund allocation for maintenance and capacity building of Teacher educators can be overcome through strategic planning and policy making at Government level.

The major role of Teacher Education institutions should not only to be updated with technologies but to provide continuous professional inputs to develop pre-service teachers' competency for effective infuse of ICT into classroom practices **(Wei, 2021).** Because at pre-service level, aim of ICT integration is not to prepare technocrats, but to develop techno-pedagogues, so that teachers would integrate technology into classroom teaching and also access information exploring internet to use that in teaching learning **(Bisht, 2013).** Thus, teacher education curriculum should be designed in such a manner to incorporate ICT into their pedagogy courses instead as an additional separate course. The Teacher education curriculum need to be critical analyzed in the present context and demand and reformed with fresh, alternative approaches to incorporate techno pedagogy in it so that the future teachers would have mastery over technical knowhow along with its pedagogical applications. Again a collaborative planning and implementation process is essential to bring the systemic change for technology use in TEIs. It is hoped that, this meta-analysis would provide a broader understanding of ICT integration into teaching and learning process, opportunities and challenges of ICT integration and pave the way for further pedagogical experiments to explore the relation between ICT integrated pedagogy and pre-service teachers' teaching competency.

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