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Evaluating the Impact of Metacognitive and Neurocognitive Interventions on Enhancing Competencies of Physics Student Teachers in Integrated B.Ed.

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Abstract: Metacognitive reflection allows teacher educators to enhance their awareness of cognitive processes and biases. It enables them to design more effective lesson plans and optimize learning techniques. This research aims to enhance the teaching competencies of physics student teachers of integrated B.Ed. by employing two distinct lesson plan models: metacognitive intervention and neurocognitive intervention. One group utilizes planning, monitoring, and evaluation to self-regulate their teaching using metacognitive intervention, while the other group employs neurocognitive interventions such as executive functioning, strategic planning, and attention. A teacher assessment rubric was devised to evaluate the teaching competencies of the participants from the groups, focusing on mastery skill, pedagogical skill, information literacy skill, problem-solving skill, and questioning skill. The study findings indicate that post-assessment of metacognitive and neurocognitive interventions provided to two separate groups (N=15 each) showed significant difference on enhancing the physics teaching competencies of integrated B.Ed. students compared to pre-assessment. Both metacognitive and neurocognitive intervention has its significance in enhancing physics teaching competencies. Consequently, teacher educators can identify areas of weakness and gaps to pursue targeted professional development opportunities that foster self-regulation and understanding of cognitive processes. The scope of this study could be expanded to explore the interventions for various disciplines and grade levels.

Keywords: Metacognition, Neurocognition, Pedagogical Skill, Lesson Planning, Intervention, Cognition, Professional Development, Cognitive Process, Teaching, Competencies

1. Introduction

Teacher education entails preparing students to become skilled teachers, scholars, and leaders in the field of education, as well as to implement reforms in learning (Trent, 2011). This consists of a number of initiatives and programmes designed to provide aspiring teachers to develop the abilities, attitudes, and information needed to be successful in their line of work (Hallam & Ireson, 2003; Donohue & Bornman, 2015; Shade & Stewart, 2001). Because universities provide undergraduate courses especially intended for students wishing to become educators, these courses constitute crucial components of teacher education in higher education on undergraduate programmes. These courses typically incorporate pedagogical strategies, principles from developmental psychology, theoretical foundations of education, and subject-specific knowledge like mathematics, science, language arts, etc. (Aglen, 2016). Practical experiences, including field internships in K–12 classrooms, are often added to academic training to improve experiential learning. For individuals pursuing higher skill, master's and doctoral degrees in teaching allow deeper research and intellectual inquiry. Graduate students can focus on a variety of topics, including special education, educational leadership, curriculum design, and teaching English as a second language (TESOL) (MULLOCK, 2006; Basheer Nomass, 2013; Tamir, 1988; Shulman, 2000). Programmes have a strong emphasis on technology integration in the classroom, efficient teaching practices, assessment procedures, and classroom management tactics. Aspiring teachers gain knowledge on how to create inclusive learning environments, accommodate a range of learning requirements, and efficiently prepare classes (Lage *et al.,* 2000).

For teacher training, hands-on experience in actual classroom situations is essential and teacher education continues with on-going professional development opportunities (Czerniawski et al., 2017). Through these programmes, educators can improve their abilities, stay current on pedagogical trends and research, and work towards practical experiences (Obidovna, 2023). In India, teacher education landscape is currently undergoing rapid changes. The transition of one-year B.Ed. Program into a two-year Program in 2015 occurred suddenly and without adequate planning. While stakeholders in teacher education continue to evaluate the merits and drawbacks of the two-year B.Ed. program, the National Education Policy (NEP) of 2020 has announced a further shift. Starting from 2030, the Integrated Teacher Education Programme (ITEP), a four-year integrated B.Ed. program, will become the sole teacher education program in the country for preparing secondary education teachers. This signals a significant transformation in teacher education. However, there is uncertainty among teacher educators, pupil-teachers, and other stakeholders regarding the implications of this change and how it will be implemented in B.Ed. colleges and university departments of teacher education. It is crucial that the vision and mission of teacher education, which profoundly influence the trajectory of school education, are clearly defined and understood (Ahmad, 2023). The policy also recommends for quality and twenty first century skills through teaching.

The growing significance of science in contemporary society has underscored the importance of science education in the 21st century. Unlike other subjects, science education holds a unique position, serving as a catalyst for promoting scientific rationality within Indian society. The core attributes of science, including open-mindedness, critical thinking, logical reasoning, rationality, brainstorming, scientific temper, inquiry, problem-solving, and scientific thinking, embody universal values essential for fostering informed citizens and advancing societal progress (Kumar & Singh, 2018). Thus, teacher education in higher education establishments is crucial to equipping aspiring educators with the skills, knowledge, and mind-set required excelling in the classroom and improving student learning outcomes at school level. It is assumed that teaching competencies are the abilities, dispositions, and knowledge that allow teachers to successfully support the growth and learning of their students. These competencies cover a broad spectrum of capabilities, such as subject matter knowledge, classroom management techniques, pedagogical competence, and interpersonal ability (Selvi, 2010).

Cognitive-based teaching interventions can excite and improve teachers and trainees in order to bring out these teaching qualities (Chung & Huang, 2021). By fostering a culture of lifelong learning and professional development and offering opportunities for further training, skill and professional development, this could increase the employability of graduates. Using technology in the classroom to help students become more digitally literate and prepare for professions in technology (Muir-Herzig, 2004; Venezky, 2004). Nonetheless, experience and training may be given to graduate teacher candidates to help them make a smooth transition into the field. These experience can be gained through cognitive related interventions and training provided with contemporary teaching competencies. However, the present curriculum in teacher education can be revamped with suitable cognitive skills fostering the teaching competencies in science can be included to meet the contemporary needs.

1.1 Metacognition and Teaching

Teachers can reflect on their own decision-making, teaching methods, and thought processes through the use of metacognition (Batha & Carroll, 2007; Basu & Dixit, 2022). Teachers can critically evaluate their pedagogy, pinpoint areas for development, and modify their strategies to better suit the requirements of their students by participating in metacognitive practices (Kudesia, 2019). Effective instructional strategies are easier to develop and apply for teachers who have high metacognitive skills. To guarantee optimal comprehension and retention, they can design classes that scaffold students' learning, assess students' knowledge in real-time, and modify their pedagogical approaches accordingly (Hennessy et al., 2007; Rocchesso *et al.,* 2013). Students are encouraged to reflect on their own thought processes and learning strategies in a student-centered learning environment, which is more likely to be fostered by metacognitive professors (Elen *et al.*, 2007; Baeten *et al.,* 2010). Teachers enable students to become self-reliant by teaching them how to keep an eye on and manage their own learning. Teachers who practice metacognition are more equipped to solve problems in the classroom and can handle challenges with greater effectiveness (Baird, 1986; Vos & de Graaff, 2004). Teachers possessing high metacognitive skills are able to handle a variety of scenarios with flexibility and inventiveness, such as regulating classroom dynamics, attending to the needs of particular students, or adjusting to unforeseen interruptions. Professional development of teachers can be aided by metacognition (Cardelle-Elawar, 1992; Wilson & Bai, 2010; Bae & Kwon, 2021; Baris, 2015). Teacher effectiveness can gradually be increased by identifying strengths and weaknesses, creating goals for professional growth, and taking proactive measures to improve teaching through metacognitive skills like action planning, goal-setting, and self-assessment (Ridley *et al.,* 1992; Akama, 2006; Gul & Shehzad, 2012). Redish delineated four overarching principles such as cognitive construction, context dependence, motivation and affect, and metacognition and self-regulation that offer a metacognitive framework for physics and other science educators. These principles aid teachers in effectively plan, monitor, and evaluate their instructional strategies, classroom activities, and learning assessments with the aim of optimizing students' comprehension of science (Redish, 1994). For effective science teaching, educators can employ metacognitive processes, engaging in high-level thinking to reflect on what, why, and how they teach. This enables them to manage and regulate their teaching approaches to better address the diverse needs of their students. Furthermore, teachers can foster students' metacognitive skills to enhance their ability to learn science. By developing students' awareness and control over themselves as learners, both intellectually and emotionally, educators empower them to engage more effectively in the learning process (Hartman, 2001). However, this could be attained when the teaching and learning embedded with cognitive skills which will effectively bring changes among the learners through metacognitive intervention based teaching.

1.2 Neurocognition and teaching

Learning involves modifications to connection, which directly affect brain function through synaptic potentiation or pruning. According to Usha Gosami, a variety of elements, such as the curriculum, teachers, classroom and home context, school environment, and community setting, are necessary for successful learning. These factors also interact with unique brain traits (Goswami, 2004). Effective learning is enhanced by successful instruction, which is referred to as "natural cognition" (M. E. Strauss & Summerfelt, 2003). All over the animal kingdom, teaching behaviors are seen, frequently having to do with getting food. On the other hand, deliberate instruction with the goal of expanding others' knowledge and incorporating a "theory of mind" seems exclusive to humans and might even be essential to their existence (S. Strauss et al., 2002). Cognitive neuroscience research has not yet thoroughly examined successful pedagogy, whereas education research concentrates on recognizing it (Churchland & Sejnowski, 1988). While some research looks at brain alterations that occur during particular educational interventions such as literacy programmes for dyslexic kids, more comprehensive investigations into the thought processes and conclusions drawn by effective instructors are still lacking.

Teachers can gain insights into how the brain stores and processes information by studying neurocognition. Teachers can adjust their teaching methods to maximize student learning results by having a thorough understanding of ideas like memory formation, attentional processes, and cognitive growth. "We were all taught forever, everyone, that forgetting is a passive breakdown of the memory mechanisms," remarks Scott A. Small, a distinguished professor specializing in neurology and psychiatry at Columbia University and the author of the 2021 publication "Forgetting: The Benefits of Not Remembering." "The fundamental insight—the eureka, I think, of the new science of forgetting—is that our neurons are endowed with a completely separate set of mechanisms … that are dedicated to active forgetting." Renowned neuroscientist Eric Kandel, recipient of the Nobel Prize, and professor of biochemistry and biophysics at Columbia University, laid the groundwork in the 1970s by demonstrating that alterations in the chemical signals among neurons constitute the biological underpinnings of all learning and memory formation. When adjacent neurons are simultaneously activated, neurotransmitter chemicals are discharged across the minuscule gap between the terminals of their slender dendrites. This modification in the synapse is the junction between neurons is what forms a memory. Educators are more adept at recognizing and addressing the diverse learning requirements of their students when they possess a thorough understanding of neurocognitive principles aimed at mitigating the effects of learning forgetting (Sneyers *et al.,* 2016; CORNNIE PURTILL, 2022). To attenuate forgetting, teachers can use varied instruction tactics to suit different learning styles, abilities, and preferences by having a thorough understanding of how students' brains function differently.

Evidence-based teaching strategies that have been shown to improve student engagement and academic achievement are informed by neurocognitive research (Diery *et al.,* 2020). Educators who possess knowledge of ideas like spaced repetition, retrieval practice, and cognitive load theory can create evaluations and activities for their students that are more successful. They can encourage metacognitive awareness in their pupils by using neurocognitive insights. They can help students become more self-regulated learners who actively assess and modify their learning practices by teaching them about how the brain processes information and retain it. They are better equipped to recognize problematic pupils and offer early intervention and assistance when they have a thorough understanding of the neurological foundations of learning issues. Teachers who see indicators of cognitive difficulties or developmental delays might work with experts to provide specialized interventions and accommodations. Anderson examines the current obstacles and complexities encountered in the advancement of comprehensive neuroscientific-based theories concerning human learning within intricate learning environments. The author delves into the analysis of significant overarching issues and conceptual dilemmas inherent in the formulation of an intermediate "neuroeducational theory," with a specific focus on mathematics and science learning (Hartman, 2001).

Meanwhile, Liu & Chiang investigate the ramifications of recent advancements in neuroscience research, utilizing these technologies to propose potential applications for both mathematics and science education research and practical implementation (Liu & Chiang, 2014). Additionally, Anderson advocates for a neuroeducational approach to understanding science learning, highlighting the difficulties in integrating various disciplinary perspectives to construct this framework. Neurocognitive-based science education is shown to enhance science learning across various contexts, encompassing diverse areas such as scientific text comprehension (Ariasi & Mason, 2014), mathematical equation strategies (SUSAC *et al.,* 2014), problem-solving techniques, and spatial problem-solving in science (Chen & Yang, 2014). Teacher education integrates neurocognitive concepts aid in the continuous professional growth of teachers. Teachers who stay up to date on cognitive neuroscience research can improve their teaching strategies and adjust to new developments in the field of education. However, neurocognition plays a critical role in teacher education because it helps teachers to personalize lessons, apply successful pedagogy, and comprehend how students learn, encourage metacognition, offer early intervention and support, and participate in on-going professional development (Yuan, 2016). Incorporating neurocognitive principles into teacher training programmes can also provide educators with the necessary knowledge and abilities to enable the best possible learning experiences for every student.

2. Theoretical Background

The study tried to develop two lesson plan model and rubrics to assess the teaching competencies. The relevance of developing two distinct model lesson plans is to reveal solution to the identified problems on enhancing teaching competencies among the student teachers during the training period. This was determined after analyzing many reviews and realizing the significance of metacognitive and neurocognitive interventions for enhancing teaching competencies. Numerous scholarly articles, publications, and research studies examine how metacognition and neurocognition help teacher educators become more proficient teachers. It is critical to comprehend the findings of the metacognition and neurocognition related research. John H. Flavell, Ann L. Brown, Schraw and many educationist offers a thorough introduction to metacognition and its uses in the classroom, along with tips for encouraging metacognitive awareness in both teachers and students (Yuan, 2016; Brown A. L., 1987; Schraw & Dennison, 1994).

The significance of metacognition in teaching and learning in several educational environments is addressed in many articles. Metacognitive knowledge is the knowledge or beliefs that are stored about tasks, activities, or tactics, about one-self and others as cognitive agents, and about how all of these interact to influence the results of any kind of intellectual endeavour (Flavell, 1979). As explained in the article "State of art - teacher effectiveness and professional learning" the major conclusions drawn are from decades of research on educational effectiveness as an indicator of student outcomes using the metacognitive approach is the significance of the effective classroom (Muijs *et al.,* 2014). In one of the study, students employed a metacognitive process-based approach to develop the problem-solving, monitoring, evaluating, and prediction/planning skills necessary for successful second-language listening (Vandergrift & Tafaghodtari, 2010). Another investigation's explains the metacognitive strategy is to teach the structure of arguments, emphasize how science and society interact, and teach argumentation through immersion in argument-based interventions in science education contexts (Cavagnetto, 2010). The research on multifaceted approach to teaching mathematics and science in heterogeneous classrooms focus on three components; metacognitive activities, peer interaction, and systematic feedback-corrective-enrichment show notable results in seventh-grade pupils (Mevarech & Kramarski, 1997).

The metacognitive intervention helps teachers identify situations in the teaching profession by helping them characterize problems and develop solutions across a wide range of classrooms with instructional variability (Lin *et al.,* 2005). However, the ability of a teacher to regulate behavior and the use of metacognitive strategies to follow a profession autonomously can be used to assess a student's learning process (ten Cate *et al.,* 2004). Teachers with a deep understanding of metacognition indicate that teaching metacognition to students necessitates an advanced understanding of both metacognitive concepts and metacognitive thinking techniques (Wilson & Bai, 2010). In addition, educators must identify the conditions that support student's metacognitive growth and assist them in becoming metacognitive aware. An essential component of learning transfer is metacognitive thinking. Metacognitive skill development in children is referred to as meta-learning. Student's metacognitive thinking can be stimulated and their metacognitive skills can be mediated by meta-teaching strategies (Fisher, 1998). Similarly for reading compression of physics texts, in-service teachers' professional development, pedagogic innovative assessment practices, organic chemistry students predicting reactivity, human robot interaction, visualization, and so on incorporated metacognitive strategies and ideals (Koch, 2001).

The reviews on neurocognitive theory and teaching offer a clearer comprehension of the significance of neurocognition in the field of education. The use of neurocognition has implications in a variety of sectors, particularly medical, brain learning, and education, has been the subject of astronomically expanding amounts of research over the past 20 years. Usha Goswami clarified the relationship between neuroscience and education in the year 2006. The benefits and virtues of neuroscience become apparent when scholars in the field, such as Bruer, Blakemore, Uta Firth, Stern, Usha Gosami, and many others, dispel the myths and neuromyths surrounding the relationship between neuroscience and education. According to Stern's explanation of the significance of neuroscience for pedagogy, it is critical that the fundamental components of neuroscience become the most pressing need for instruction. It is imperative that educators embrace the principles of neuroscience in their instruction to ensure the well-being of their students "Class teachers will take on new initiatives if they are sold on the benefits for the children. Ultimately this is where brains live!" (Goswami, 2006). When educational interventions coincide with improvements in synaptic density, they may have greater efficacy.

Neuroscience might be able to provide more evidence than psychological theories for how past experiences can enhance learning. While a plethora of research has demonstrated the profound influence of past knowledge of skills, procedures, or concepts on learning, there might be alternative approaches to enhance learning beyond this kind of information transfer. In specific brain regions, cognitive activities can activate specific neural processes by inducing electrical impulses and neurotransmitter release. Even when two cognitive processes involve entirely different knowledge structures, they may be increased concurrently if they are processed in identical brain locations. Neuroscience cannot supply the specific knowledge needed to create effective learning environments in certain academic subjects on its own. But neuroscience can assist explain why some learning settings are successful while others are not by shedding light on the capacities and limitations of the learning brain. Neuroscience has the potential to contribute to the design of the classroom of the future as part of interdisciplinary collaboration (Stern, 2005). One of the examples stated by Kiefer and Trumpp "Imagine that you are a teacher and that you would like to introduce your students to the bassoon, which is a new musical instrument". She or he has multiple options for imparting the necessary knowledge. For example (i), the instructor can explain this musical instrument's form, composition, sound, application, etc. (ii) The instructor might play a video that illustrates the structure, tone, and application of a bassoon. (iii) The instructor could accompany the class to an orchestra so they can see a bassoonist perform live and have the opportunity to touch or play the instrument. These many approaches of teaching the bassoon may promote learning in different ways. This tries to comprehend that the reinstatement of external (perception) and internal (proprioception, emotion, and introspection) states, along with physical activities that generate simulations of past experiences, are fundamental foundations for cognition and logical thinking (Kiefer & Trumpp, 2012).

However, to accomplish such an effective teaching the teachers are necessary to design lesson plan encompass the methods, instructional aids, strategies, activities, techniques and the needed methodology to handle the class. The lesson plan and execution of the planned lessons is complex to align across the proposed aim, steps and evaluation (Liyanage & Bartlett, 2010). Self-regulating the instructional plan by planning, monitoring evaluating is difficult and it acquires series of training for any subject (Hiller S.E., 2017). The lesson plan template filled with cognitive skills and identifying the pedagogical moves can promote understanding of science concepts (Wallace & Coffey, 2019). The above conceptual framework in Figure 1 deliberates on how metacognitive and neurocognitive intervention is given to two different groups using two distinct model lesson plans. As well what are the teaching competencies of the integrated B.Ed. students before and after the intervention using the analytical rubrics are assessed. In order to improve teaching competencies among the physics student teachers, this study investigates with metacognitive and neurocognitive intervention techniques. It fills up experimental research gaps and creates a comprehensive foundation for student teachers of integrated B.Ed. Through this research, the aim is to empower student teachers with the tools and strategies needed to create engaging, inclusive, and effective learning environments, ultimately benefiting students and advancing the field of education.

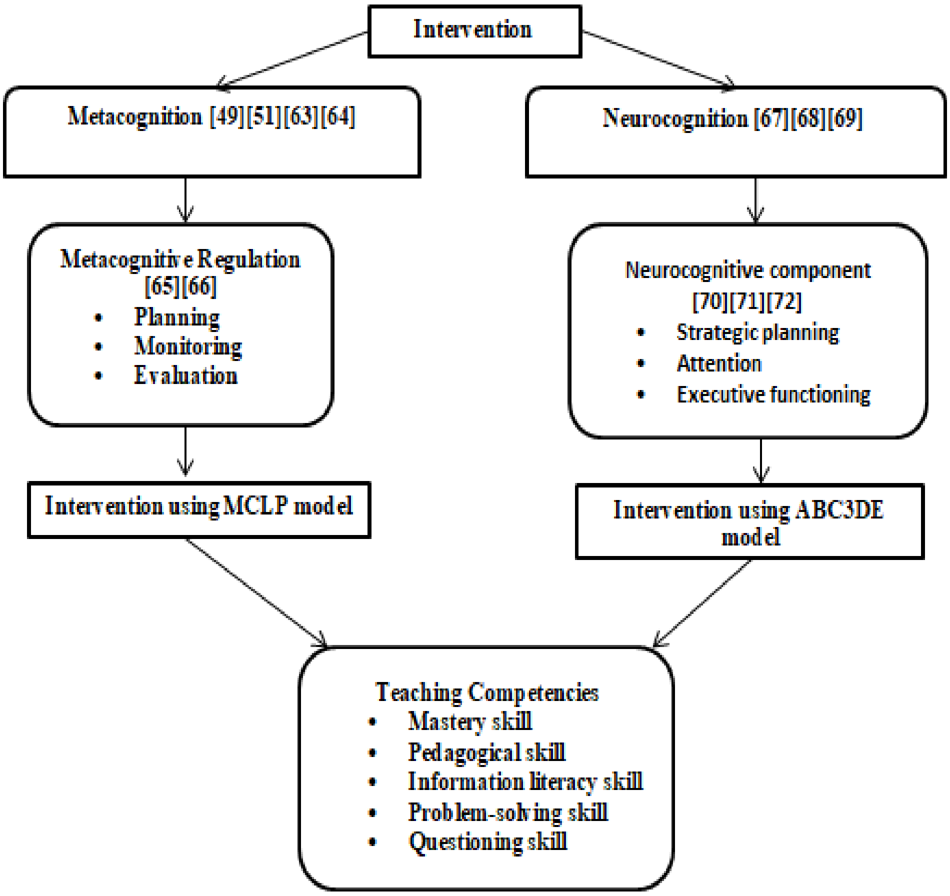

Figure 1. Conceptual framework of the study (Brown A. L., 1987; Flavell, 1976; Flavell, 1979; Paris & Winograd, 1990; Schraw & Moshman, 1995; Schraw, 2006; Gazzaniga, 1987; Kosslyn, S. M., & Koenig, 1992; Squire & Wixted, 2011; Balconi et al., 2023; Anderson, 1998; Mesulam, 1990)

3. Methods and Evaluation Rubrics

Professionally trained educators will have the abilities to incorporate technology and cognitive strategies into their lesson plans with ease in the future. Lack of cognitive skills, knowledge of various learning styles, developing successful lesson plans, subject matter mastery, executive functioning abilities, modifying teaching strategies, maintaining student interest, and assessing results are some of the challenges that have been discovered. In order to accommodate the diverse demands of pupils, it becomes necessary to use cognitive-based teaching strategies. Research on metacognitive intervention has produced a lot of good results over the last 50 years for addressing a range of learning difficulties. To address the problems, the researcher chose to use metacognitive intervention, which involves regulating instructional methods through the use of planning, monitoring, and evaluation methodologies. Furthermore, issues with cognitive abilities, the efficacy of lesson preparation, and topic mastery were addressed in this study by utilising elements of neurocognitive intervention, such as executive functioning, attention, and strategic planning (Balconi *et al.,* 2023; Mesulam, 1990; Anderson, 1998). Post-intervention teaching competence of integrated B.Ed. students was evaluated in terms of mastery, pedagogical skills, information literacy, problem-solving aptitude, and questioning strategies using Teaching Assessment Rubrics (TAR) designed by the researcher and validated. This was elaborated under the section; methods, evaluation rubrics and assessment mechanism.

3.1 Methods

This study aims to develop a metacognitive and neurocognitive intervention to enhance teaching competencies specifically in the field of physics. The researcher utilized two intervention approaches: the Metacognitive Lesson Plan (MCLP) intervention was applied to one group of participants' a. to foster the development of cognitive regulation in teaching styles b. to establish a self-directed plan of action using MCLP c. to monitor the plan for set induction, lesson introduction, and selection of appropriate methods/techniques/strategies/technology d. to evaluate the adopted teaching style and assess students' comprehension. Whereas the Ability to Bring out Cognitive Strategies to Define, Demonstrate, Deliver, and Evaluate (ABC3DE) intervention was applied to another group a. to adoptive readiness for experiencing Physics teaching competencies b. to choose cognitive-based teaching methods for the topics at hand c. to identify appropriate information technology tools for teaching d. to teach cognitive strategies to enhance learners' comprehension e. to improve contemporary pedagogical skills. Subsequently, the TAR was employed to assess the teaching performance of students after the intervention. The study opted for a quasi-experimental research design to evaluate the interventions implemented in two distinct groups. This experimental approach was chosen to meticulously control potential threats and enhance external validity, ensuring a robust assessment of the interventions' effectiveness.

3.2 Research Questions

The following research questions were addressed to study the impact of metacognitive and neurocognitive intervention to enhance the teaching competencies among the physics student teachers of integrated B.Ed.

R1. Does metacognitive intervention enhance teaching competence?

R2. Does neurocognitive intervention enhance teaching competence?

R3. Is there any difference in mastery skill, pedagogical skill, information literacy skill, problem solving skill, questioning skill between the pre-assessment and Post-assessment of metacognitive intervention?

R4. Is there any difference in mastery skill, pedagogical skill, information literacy skill, problem solving skill, questioning skill between the Pre-assessment and Post-assessment of neurocognitive intervention?

R5. Is there any difference in enhancing the teaching competencies between metacognitive and neurocognitive intervention?

3.3 Participants

The study comprises convenient sampling of 30 Integrated B.Ed. students from Physics. Based on their academic performance in their degree programme the 30 participants were randomly selected into two groups of 15 participants each. One group underwent MCLP metacognitive intervention, while the other received ABC3DE neurocognitive intervention. The two distinct lesson plan model was explained below. The MCLP model is elucidated in Table 1.

The MCLP model served as the metacognitive intervention for group one (GI), where participants underwent training to develop lesson plans based on these interventions, followed by analysis of their teaching competencies. The MCLP model intervention encompassed planning, monitoring, and evaluation, aiming to assist student teachers in effectively planning and executing lessons. By employing this intervention, student teachers gained insights into the importance of lesson planning and self-regulation in teaching. They also discerned disparities between their own teaching performances when utilizing the MCLP model compared to conventional lesson plans.

3.4 Evaluation Rubrics

The evaluation of teaching competencies among integrated B.Ed. students in two distinct experimental groups was conducted utilizing the Teacher Assessment Rubrics (TAR).

Table 1. Metacognitive lesson plan (MCLP) model

<table>
<tr><th colspan="3">The lesson plan model for MCLP metacognitive intervention</th></tr>
<tr><td colspan="3">Subject: Physics Topic: Introduction to Solid State Physics
Class: B.Sc.B.Ed. Physics Duration: 40 minutes</td></tr>
<tr><td colspan="3">Instructional Objectives
• To describe the fundamental concepts utilized in delineating the structure and physical attributes of crystalline substances.
• To employ calculations of solid properties for the creation of physical models.
• To apply principles related to the physical phenomena addressed within this topic.</td></tr>
<tr><td colspan="3">Intervention
• Planning
• Monitoring
• Evaluation</td></tr>
<tr><td colspan="3">Teacher Activity
Planning (Completed one to two days prior):
• Have I planned a structured lesson plan for delivering the topic on condensed matter systems?
• Am I prepared to introduce the concept effectively by motivating students to engage with new knowledge?
• Have I selected suitable instructional materials and identified potential resources to support my teaching?
• Do I know how to choose the most appropriate teaching methods for explaining the concepts related to condensed matter systems?
• Have I incorporated real-life examples to ensure a thorough understanding of the topic?
• Have I planned a classroom activity to facilitate students' appreciation of the concepts being taught?
• Have I included opportunities to pose questions during the teaching process to encourage active participation and critical thinking among the learners?</td></tr>
<tr><td colspan="3">Classroom Activity</td></tr>
<tr><td>Phase</td><td>Teaching Experience</td><td>Student Involvement</td></tr>
<tr><td>• Monitoring(During teaching)
Set Induction</td><td>To check the entry behavior of the learner the following questions were asked.
What is matter?</td><td>The three kinds of matter are solid, liquid and gas. By answering the questions the students' attention was captured to listen the new concept.</td></tr>
<tr><td>Introduction</td><td>The teacher shows the three kinds of matter. The teacher continues introducing the content by posing questions and using the instructional material.
How do you classify based on the arrangement of atoms?</td><td>Arouse interest to perceive new knowledge.

In solid the atoms are tightly bound, in liquid atoms are closed but no regular arrangement and in gas irregular arrangement and well separated.</td></tr>
<tr><td>Development of the lesson</td><td>Describes the subject content on lattice point and observes the students listening.
Illustrating the concept of material science with different examples.
Uses the slides to correlate the concept of electronic band structure for more understanding.</td><td>Observe the class and participate in class discussion.

Performs the activity and understands the new concept.</td></tr>
<tr><td>• Evaluation</td><td>Clarify the conceptual of the solid state physics and types of lattice.
Recapitulate the content and conduct short activities on classification of</td><td></td></tr>
</table>

	materials to assess the learners' understanding.	
Teacher student Activity		
Method	**Teacher Activity**	**Student Activity**
Lecture	Describes or explains or Illustrates (with or without aids)	Listens
Drawing practice	Draws a diagram on the chalkboard	Looks at the diagram Observes the method of drawing and practices
Questioning	Asks questions and provides feedback	Answers the questions
Tutorial	Guides the students	Solves the problems
Discussion	Leads discussion	Participates in discussions
Demonstration	Demonstrates	Observes
Class activity	Leads with ideas	Participates in activity
Learning Outcome in using MCLP • Regulation of cognition in their teaching style. • Self-determined plan of action using MCLP. • The plan and monitor for set induction, introducing the lesson, selection of appropriate methods/techniques/strategies and self-monitoring their teaching. • Self-evaluation on their teaching style adopted and to assess the students' understanding.		

These rubrics, devised by the researcher, underwent iterative refinement processes incorporating feedback from the academic guide and subject matter experts. The content validity and reliability of the analytic type of rubric TAR was done (Jonsson & Svingby, 2007).

Table 2. The components and sub-scale used in TAR

Components	Sub-scale
Mastery skill	• Strong on basic principles of Physics • Physics knowledge • Known to interpret the misconception in teaching concept • Competent in attention, acquisition, and ascension
Pedagogical skill	• Selection of suitable teaching methods • Passion of teaching • Skill of acquiring sustained attention • Level of language expressions • Black board usage skill • Interactive skill
Information literacy skill	• Basic computing skills in teaching • Used Flipped/blended/animated videos in teaching • Known to incorporate online teaching methodology • Usage of IT in teaching
Problem-solving skill	• Defined the problems clearly • Given brainstorming ideas to solve • Enumerated the problems to arriving the correct solution • Interpreted the evaluated outcome
Questioning skill	• Posed factual type of questions (What/When) • Interpretive type of questions were raised (Why/How) • Recall/Recognition type of questions were used • Focused on posing higher order level of questions

The reliability of the TAR is found to be α =0.809 using Cronbach's Alpha statistical method. The TAR comprises five key components aimed at assessing teaching competence: mastery skill, pedagogical skill, information literacy skill, problem-solving skill, and questioning skill. Each component is meticulously evaluated against predefined criteria delineated as 'Accomplished,' 'Satisfactory,' 'Marginal,' and 'Incompetent.' The detailed breakdown of these components and their respective sub-scales utilized for teaching assessment is comprehensively elucidated in Table 2.

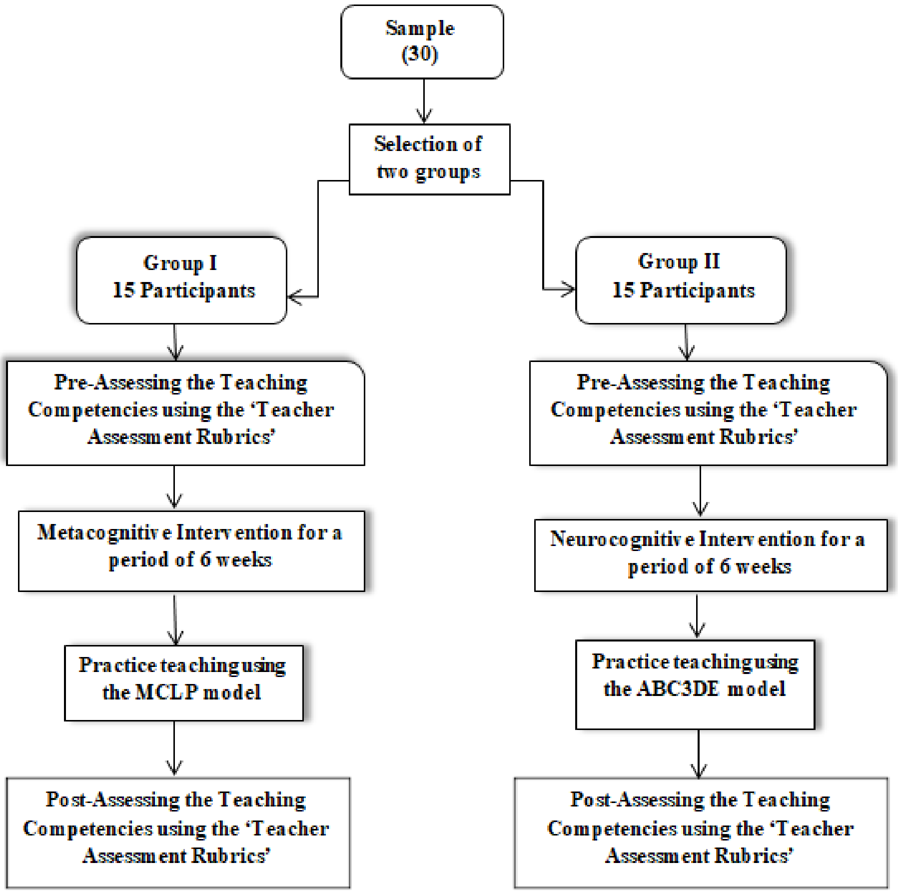

Figure 2. Assessment mechanism

The Figure 2 elucidates the assessment mechanism for the two distinct groups using TAR. The evaluation rubrics TAR used in both pre-assessment and post-assessment helps in identifying the teaching competencies of the student teachers such as their depth in subject knowledge, usage of effective teaching strategies and instructional aids, their technological skill incorporated in teaching. As well the most needed skill for the science teacher is problem solving and questioning skill. After selecting randomly, the 15 participants of GI were pre-assessed using TAR and their evaluation was recorded. It is found that their teaching performances of integrated B.Ed. are needed to be improved. The instructor gave six weeks of metacognitive intervention to the integrated B.Ed. students. There is an hour-long teaching session three days in a week. It is open to the participants to identify the variations in the instructional approaches employed. There was a free-flowing discussion to clear up any questions on how the teaching material was organized at the conclusion of each session. The following steps were covered in the training for the participants on how to plan and carry out the metacognitive lesson plan.

I. Selection of the teaching content. (Planning)

II. Selection of technology, activity, and resource materials to be used. (Planning)

III. Organisation of the materials, resources for teaching. (Monitoring)

IV. Implementation of the planned teaching content using technology.(Monitoring)

V. Discussion on taught content with planned out and comparing with the previous teaching. (Evaluation)

The researcher developed a model lesson plan tailored for the "Solid State Physics" syllabus, integrating the MCLP intervention. This comprehensive approach involved six teaching sessions, five practice sessions, and three discussion sessions to underscore the importance of implementing metacognitive techniques within the classroom setting. Participants from G I underwent training in teaching methodologies infused with metacognitive intervention and were guided in crafting lesson plans following this approach. An orientation session on MCLP preparation was conducted to familiarize participants with the methodology. Subsequently, using metacognitive interventions encompassing planning, monitoring, and evaluation, participants formulated their lesson plans and engaged in teaching practice sessions. Participants precisely devised their lesson plans, deliberated on teaching strategies incorporating technologically enhanced instructional aids, and crafted questions for classroom engagement. The instructional sessions coordinated by participant’s seamlessly integrated technology while regulating metacognitive processes in teaching. Participants actively raised queries and implemented assessment activities to evaluate their teaching methodologies. The researcher conducted a post-assessment over a period of 15 days to evaluate the teaching competencies of GI following the intervention, utilizing the TAR. The ratings obtained from the post-assessment, aimed at assessing teaching competencies, were juxtaposed with those from the pre-assessment phase. Conversely, group two (G II) received instruction based on the ABC3DE model lesson plan, as outlined in Table 3.

Table 3. Ability to Bring out Cognitive Strategies to Define, Demonstrate, Deliver, and Evaluate (ABC3DE) model

<table>
<tr><th colspan="3">The lesson plan model for ABC3DE neurocognitive intervention</th></tr>
<tr><td colspan="3">Subject: Physics Topic: Introduction to Solid State Physics
Class: B.Sc.B.Ed. Physics Duration: 40 minutes</td></tr>
<tr><td colspan="3">Instructional Objectives
• To elucidate the fundamental principles for describing the crystalline substance structure and its physical properties.
• To utilize the solid property calculations for constructing physical models
• To apply insights into relevant physical phenomena within this field.</td></tr>
<tr><td colspan="3">Intervention</td></tr>
<tr><td colspan="2">Cognitive function</td><td>Phase of ABC3DE lesson plan</td></tr>
<tr><td colspan="2">Strategic planning</td><td>ABC3DE</td></tr>
<tr><td colspan="2">Attention</td><td>BC3D</td></tr>
<tr><td colspan="2">Executive function</td><td>B3DE</td></tr>
<tr><td colspan="3">Teacher activity</td></tr>
<tr><td colspan="3"><u>A</u>bility
• Self-assuring subject depth on condensed matter systems.
• To assimilate and accommodate the theoretical concepts of condensed matter systems.
• Familiarize yourself in transacting the theory to practice.
• Collecting possible resources for teaching.
• Selection of appropriate instructional methods and cognitive strategies.</td></tr>
<tr><td colspan="3"><u>C</u>ognitive strategies (Applied during the class)
• Creation of concept mapping/mind mapping on condensed matter systems.
• Synthesis of animated videos to classify the condensed matter system.
• Planning of flipped class for sequence delivery of content.</td></tr>
<tr><td>Specification</td><td>Teaching Learning Experience</td><td>Cognitive Strategies</td></tr>
<tr><td><u>B</u>ring out

<u>D</u>efine</td><td>Testing previous knowledge by asking the following questions.
1. Define matter
2. Which type of matter involves the properties of condensation?
3. Imagine, if water falls suddenly freeze then what physical changes do you observe?
Defining the meaning of condensed matter systems.</td><td>The matter is defined as solid, liquid, and gas. (Recognize)
The matter changes from the gaseous phase into the liquid phase. (Analyze)
The students will answer through sensory perception ‘Liquid to solid’.
Critical thinking is improved.</td></tr>
</table>

Demonstrate	Demonstrating the concept of material sciences using concept mapping and videos. (Constructivist)	Visualizing mind maps/concept mapping and trying for an activity to draw concept maps. (creative thinking)
Deliver	Deliver the theoretical views on electronic band structure, its practicability, mathematical equations, analytical concepts and its application.	Creating sensory impacts through flipping the slides and interaction with the students.
Evaluation	What is theoretical condensed matter Physics? Why is it important? Graded quizzes assigned online to assess their level of understanding.	Students will recall the need and importance of condensed matter systems. Gives response to the graded questions.

Learning outcome in using ABC3DE model

- Hands-on experience improves problem solving skill. (executive functioning)
- Integration of technology to facilitate skill acquisition and flipped classroom dynamics helps to bring attention among the learners.
- Selection of cognitive strategies to improve learner's comprehension develops strategic planning.
- Modern pedagogical techniques for effective teaching bring cognitive flexibility. (executive functioning)

The ABC3DE neurocognitive intervention was administered to the second group, wherein participants were tasked with developing lesson plans integrating these interventions, subsequently evaluating their teaching competencies. Student teachers were provided with comprehensive guidance on utilizing the ABC3DE model, enabling them to familiarize themselves with its principles. The neurocognitive intervention facilitated intrinsic changes in their teaching behaviors by fostering a connection between mind and body. This cognitive regulation equipped student teachers with the necessary skills to effectively engage in their teaching practice. The remaining 15 students from G2 selected randomly were undergone neurocognitive intervention. Over a span of 6 weeks, the investigator conducted classes, dividing into 6 demonstration sessions, 5 for practical teaching exercises, and 3 sessions designated for discussion and clarification. The neurocognitive intervention focused on enhancing attention, strategic planning, and executive functioning to facilitate teaching grounded in neurocognitive principles. Participants engaged in the teaching sessions and scrutinized the varied instructional strategies employed. At the conclusion of each teaching session, students were allotted time to reflect, providing them with diverse perspectives on delivering instructional concepts. The procedural steps of the ABC3DE model are outlined below.

Step 1: Strategic Planning on

- designing the lesson plan
- determined objectives
- verbalizing the lesson plan
- defining the concepts
- linking practical examples.

Step 2: Attention by

- directing student's attention towards listening the teaching
- integrating technology in teaching
- posing questions
- swapping the instructional aids
- switching the teaching approach
- grabbing the attention till the end of the session

Step 3: Executive functioning for

- execution of planned lessons

- self-monitoring the comprehensive teaching
- prioritizing the technology aid in teaching
- cognitive based task initiation and organization
- flexible thinking to change learner's behavior

The researcher implemented the aforementioned procedures to introduce the ABC3DE lesson plan model. These lessons were structured around the topic of "Solid State Physics," as outlined in the syllabus. Participants were exposed to a distinct learning environment. Following the sessions, participants were encouraged to share their perspectives on the instructional methods observed, with any uncertainties addressed through group discussion. Subsequently, during the post-assessment phase, the 15 participants in G II were afforded time to assess variances in teaching strategies employed during the intervention sessions. Participants acknowledged and appreciated the skills and strategies employed by the researcher in both the planning and execution stages of instruction. They gained insight into the teacher's role and responsibilities in capturing students' attention while disseminating educational content. Furthermore, participants were trained to formulate lesson plans utilizing the ABC3DE model, comprehending the intricacies of strategic planning, attention, and executive functioning. They recognized the significance of neurocognitive interventions in pedagogy. Given the experiential nature of the intervention, participants internalized the model's components, consequently prepared lesson plans employing the ABC3DE framework. The researcher evaluated the teaching competencies of G II participants' post-intervention using the Teaching Assessment Rubric (TAR), with teaching observations conducted over a 15-day period and ratings recorded. The assessment of the teaching competencies before and after intervention was discussed in the next section.

4. Result and Discussion

The analysis on metacognitive intervention for MCLP model using TAR is presented in Table 4, delineates the mean, standard deviation, and t-values derived from both pre-assessment and post-assessment datasets.

Table 4. Mean, standard deviation and t-value for metacognitive intervention

Metacognitive Intervention	Mean	N	Standard Deviation	Standard deviation between pre-test and post-test intervention	df	t-value	Sig.
Pre-test	15.9333	15	4.74291	2.84019	14	20.545	0.000
Post-test	31.0000	15	3.16228				

From Table 4 the results indicate a significant improvement in the performance of the participants following the metacognitive intervention. The intervention shows a notable increase in mean scores that proved the effectiveness of metacognitive strategies for developing learner self-regulation and awareness. The intervention seemed to produce a consistent performance among test participants based on their lower post-test standard deviation. A very significant t-value combined with a p-value supports the statistical analysis which proves the improvement does not stem from random events. Hence, by analysing the research question R1 it was found that the metacognitive interventions of post-test shows high significant difference when compared to pre-test without intervention.

Similarly, to understand the teaching competencies of G I integrated B.Ed. Physics before and after the intervention of MCLP can be obtained from the Table 5.

The teaching competencies of students pursuing an integrated B.Ed. program in Physics were evaluated both before and after the implementation of metacognitive intervention MCLP. The findings from Table 5 indicate significant improvements in teaching mastery skills among student teachers. Analysis reveals a substantial disparity between the pre-test and post-test mean values, with a standard deviation of 0.84515. The computed t-value exceeds the critical value, indicating that metacognitive intervention significantly contributed to the enhancement of mastery skills among student teachers. Similarly, other teaching competencies such as pedagogical skills, information literacy skills, problem-solving skills, and questioning skills also exhibited notable improvements. Notably, the post-test mean value for pedagogical skills surpassed the pre-test mean, with a standard deviation of 0.82808. The calculated t-value indicates a substantial improvement in pedagogical skills, surpassing the critical value. Likewise, the post-test mean value for information literacy skills exceeded the pre-test value, with a standard deviation of 1.08233. The t-value exceeds the critical value signifying enhanced information literacy skills following metacognitive intervention. Similarly, the post-test mean values for problem-solving skills and questioning skills exceeded the pre-test means, as well the value of standard deviations of both the skills. The calculated t-values of problem-solving skills and questioning skills exceeded the critical values, indicating significant enhancements attributed to metacognitive intervention. Therefore, by analysing the research question R2 the post-test results underscore a noteworthy improvement in teaching competencies among integrated B.Ed. students subsequent to metacognitive intervention, as compared to pre-test assessments conducted without intervention. The metacognitive intervention led to substantial advancements in multiple domains of teaching competencies. The intervention led teachers to develop superior subject-matter and pedagogical knowledge which demonstrated their enhanced understanding of instructional methods and classroom strategies. The intervention achieved successful metacognitive awareness and teaching proficiency promotion as shown by the high statistical significance across all tested dimensions because these important improvements are not random occurrences.

Consequent to data collection, the post-assessment ratings were compared with participants' pre-assessment ratings, with the outcomes delineated in Table 6.

Table 5. Comparison of teaching competence between the pre-test and post-test of metacognitive intervention

Teaching competence	Pre-test Mean	Post-test Mean	N	Standard deviation	t-value	df	Sig.
Mastery Skill	4.2000	7.2000	15	0.84515	13.748	14	0.000
Pedagogical skill	7.0667	10.6667	15	0.82808	16.837	14	0.000
Information literacy skill	1.3333	4.5333	15	1.08233	11.451	14	0.000
Problem solving skill	1.6000	3.8000	15	1.14642	7.432	14	0.000
Questioning skill	1.7333	4.8000	15	1.22280	9.713	14	0.000

Table 6. Mean, standard deviation and t-value for neurocognitive intervention

Neurocognitive Intervention	Mean	N	Standard Deviation	Standard deviation between pre-test and post-test intervention	df	t-value	Sig.
Pre-test	15.5333	15	2.38647	2.80815	14	34.204	0.000
Post-test	40.3333	15	2.35028				

From the Table 6 the mean and standard deviation of the G II before treatment, and the mean and standard deviation after the neurocognitive intervention ABC3DE indicate that the neurocognitive intervention developed important improvements in cognitive ability. The t-value which is much greater than the table value infers that there is a high significant difference between the pre-test and post-test. The intervention shows strong positive effects on cognitive performance through its substantial impact on mean scores which most likely strengthens attention abilities alongside memory operations and executive control functions. Therefore, the research question R3 results that neurocognitive intervention enhances the teaching competencies among the integrated B.Ed. students. Meanwhile, the G II teaching competencies before and after intervention were obtained from Table 7.

The teaching competencies of group two of integrated B.Ed. was analysed before and after the neurocognitive intervention. The results are observed from the Table 7. The post-test mean value of the teaching competence, mastery skill is greater than the pre-test value. The t-value of mastery skill observed a greater value compared with the table value. Therefore the students of integrated B.Ed. improved their mastery skill after the neurocognitive intervention. While analysing the other teaching competencies such as pedagogical skill, information literacy skill, problem solving skill, and questioning skill, the mean values of post-test is higher than the pre-test value. The results indicate a significant improvement in various aspects of teaching competence following the neurocognitive intervention according to research results for R4. An enhanced ability to process information, problem solving and questioning skill demonstrates better critical thinking alongside enhanced classroom adaptability. The high statistical significance results for all competencies prove that the improvements are not random phenomena because the intervention effectively develops teaching skills and cognitive flexibility. Hence, the neurocognitive intervention has effective improvement in teaching competencies among the students of integrated B.Ed.

Table 7. Difference in teaching competence between the pre-test and post-test of neurocognitive intervention

Teaching competence	Pre-test Mean	Post-test Mean	N	Standard deviation	t-value	df	Sig.
Mastery Skill	4.2000	8.3333	15	1.45733	10.985	14	0.000
Pedagogical skill	5.7333	10.5333	15	1.37321	13.538	14	0.000
Information literacy skill	2.0667	7.3333	15	1.33452	15.285	14	0.000
Problem solving skill	1.5333	6.8667	15	1.04654	19.737	14	0.000
Questioning skill	2.0000	7.2667	15	1.03280	19.750	14	0.000

Table 8. Teaching competencies between metacognitive and neurocognitive intervention

Intervention	Test	Mean	N	Standard Deviation
Metacognitive	Pre-test	15.9333	15	4.74291
	Post-test	31.0000	15	3.16228
Neurocognitive	Pre-test	15.5333	15	2.38647
	Post-test	40.3333	15	2.35028

The difference in enhancing the teaching competencies between the metacognitive and neurocognitive intervention is represented in the Table 8. The statistical analysis of R5 revealed that teaching competencies improved substantially when using either metacognitive or neurocognitive interventions because post-test results surpassed pre-test results. The neurocognitive intervention resulted in better teaching competency compared to metacognitive approach because the post-test scores yielded by the independent t-test analysis. Thus neurocognitive intervention which includes strategic planning, executive function development and attention regulation proves more beneficial than techniques based on metacognitive self-regulation and awareness. Professional development programs targeting instructional effectiveness can benefit from neurocognitive-based approaches according to the studied significant differences between methods. This research supports the integration of neurocognitive principles in teacher training approaches as it contributes to existing studies to enhance competencies among the student teachers of integrated B.Ed.

5. Conclusion

Learners' attention, interest, attitude, perception and all psychological terminology to represents learning situation can be brought meaning and effective only when teaching becomes effective. To achieve the above said environment the teacher who deliberates at every sequence of his/her teaching should possess good teaching competencies. This study tried to create such like environment through metacognitive and neurocognitive intervention based teaching competencies. Metacognition and Neurocognition present multifaceted advantages for enhancing pedagogical aptitude among educator trainers, encompassing heightened introspection, refined pedagogical design, and proficient adaptation, as well as streamlined evaluation methodologies, advocacy for continual professional growth, and augmented professional advancement. By integrating these cognitive frameworks into educational curricula, academic institutions can better equip instructors to address the heterogeneous needs of their learners and foster substantive learning encounters within educational settings. The instructional framework delineated within this research may be further refined contingent upon subject matter, curriculum content, and contextual teaching dynamics to maximize the efficacy of pedagogical interventions. Moreover, the assessment rubrics, such as the Teaching Assessment Rubric (TAR), can be tailored to suit the demands of diverse academic domains and contemporaneous educational requisites. Both interventions notably augment the pedagogical proficiencies of educators. Further, bridging the significance of both metacognition and neurocognition and finds the effectiveness of intervention in enhancing the teaching competencies. This can also be evaluated for in-service teachers to knit the cognitive based teaching to meet the contemporary need. Future studies could explore the long-term impact of metacognitive and neurocognitive interventions on teaching competencies across diverse educational contexts. Investigating their effectiveness in different subject areas, grade levels, and cultural settings would provide deeper insights into their adaptability and scalability. Additionally, research could examine how these cognitive-based approaches influence student learning outcomes and engagement. Further exploration of tailored assessment tools, such as modifications to the Teaching Assessment Rubric (TAR), could enhance evaluation precision. Finally, studying the integration of these interventions in in-service teacher training programs would help bridge research findings with real-world classroom applications.

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Author Contribution

V. Devaki – Conceptualization, Methodology, Results analsysis, Writing Original Manuscript, E. Ramganesh - Writing Review & Editing., S. Amutha - Writing Review & Editing. All the authors read and approved the final version of the manuscript.

Does this article screen for similarity?

Yes

Ethics approval

No ethical clearance certificate is applicable for this present study.

Conflict of Interest

The authors have no conflicts of interest to declare. There is also no financial interest to report. The author certifies that the submission is original work and is not under review at any other publication.

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