Metacognitive Model of the Science Teachers' TPACK in Butuan City, Caraga Philippines

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ABSTRACT

The study determined the Technological Pedagogical and Content Knowledge (TPACK) of the JHS science teachers and established the metacognitive model. It employed descriptive-correlational design to determine the level of TPACK of the Junior High School Science teachers, and the types of metacognitive strategies applied by the teacher in the classroom. Seventy (70) JHS Science teachers handling different year levels from Grades 7-10 in the identified public and private Junior High Schools in Butuan City were involved in the study. Results showed that the JHS Science Teachers had a high level of TPACK. The teachers' highest level of TPACK was in the area of Learning Environment and Assessment. However, the teachers could improve their TPACK in the areas of Content & Pedagogy and Learners' Diversity. The JHS science teachers implemented a variety of metacognitive strategies to effectively manage their TPACK, particularly close reading and reflection questions. However, there was limited usage of metacognitive strategies such as comparing and contrasting concepts and monitoring the learning process. The measurement model showed that the latent variables are well-measured by their observed variables. Thus, in the formative model, the metacognitive indicators would aid in the development of TPACK. School administrators may focus on developing teachers' TPACK and metacognitive processing skills to enhance teachers teaching effectiveness.

Keywords: Formative Model, Learners' Diversity, Metacognition, Metacognitive Model, Pedagogy, Technological Pedagogical and Content Knowledge (TPACK)

INTRODUCTION

The vision for the future of education which is Education 4.0 is responding to the needs of the Fourth Industrial Revolution or Industry 4.0 (Gagnidze, 2020). This implies that the digital technologies must be harnessed and utilized, and the blueprint for lifelong learning must be established. Considering Education 4.0, the 21st-century learning framework emphasizes the development of 21st century skills such as creativity, communication, critical thinking, collaboration, digital literacy, and problem-solving skills (Shah room & Hussin, 2018). These 21st century skills are very significant because the development of these skills can help the students succeed in contemporary times making the students not just locally competitive but also globally competitive.

Driven by the evolving demands of 21st-century learning, universities and colleges across the country have proactively embarked on a journey to revitalize their Teacher Education Curricula and Programs. This commitment to pedagogical innovation underscores the pivotal role of higher education institutions in fostering quality education, particularly in the field of science (CHED Memorandum Order (CMO) No. 13, series of 2020). Teacher education institutions (TEIs) are entrusted with developing future teachers who are well-versed in science curriculum and pedagogy. If the Science teachers' initial training provided the teachers with sufficient experience, new teachers would have a greater understanding of effective pedagogical practices (Antipolo & Royagan, 2021).

To cultivate a generation of functionally literate and scientifically minded citizens, it is imperative to equip teachers with the requisite skills and knowledge. This necessitates a comprehensive approach that encompasses pedagogical training, subject matter expertise, and the ability to nurture analytical thinking skills and problem -solving skills in students (Laguatan & Abad, 2019). In the face of a rapidly evolving world, Teacher Education Institutions (TEI's) shoulder a critical responsibility to equip science teachers with global competitiveness, technological fluency, and well-grounded ethical values. The New Teacher Education Program (NTEP) is forging a new breed of educators. These teachers are not simply content experts, but pedagogical masters equipped to navigate the diverse landscape of Basic Education. New Teacher Education Program (NTEP) graduates are more than mere teachers – they are reflective practitioners, driven by a deep understanding of the teaching profession and a commitment to ensure continuous improvement. Their journey extends beyond the traditional classroom, embracing innovative teaching practices fueled by critical thinking and creative technology integration (Slade et al., 2019).

Pedagogical Content Knowledge (PCK) is a cornerstone of the Outcomes Based Teacher Education (OBTE) curriculum, particularly within the Content Specialization component. The emphasis on Pedagogical Content Knowledge highlights the multifaceted nature of effective teaching. Pre-service and in-service teachers must not only possess deep subject matter expertise but should also master the art of translating their PCK into engaging and accessible learning experiences for diverse students (CHED Memorandum Order (CMO) No. 13, series of 2020). So outcomes determine the curriculum content, the teaching methodologies and practices, and the assessment processes for constructive alignment. For teachers, the area of outcomes assessment is on specialization in terms of pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological pedagogical content knowledge (TPCK), and practicum. Hence, teaching and learning thrive within a holistic system where all facets of instruction and evaluation are meticulously aligned to foster high-level learning.

Metacognition is the overarching cognitive process that involves actively managing and controlling one's own learning. It encompasses a range of higher-order thinking skills that enable individuals to effectively plan, monitor, and evaluate their learning progress (Zhen et al., 2019). Metacognition, the ability to self-regulate one's learning processes, is a crucial determinant of successful learning. Understanding and fostering metacognitive development is essential to empower learners to effectively utilize their cognitive resources and achieve their learning goals (Tanner, 2018).

Metacognition and TPACK are complementary constructs that are essential for effective teaching and learning. By fostering metacognitive development and integrating technology into instruction in a TPACK-based manner, educators can empower learners to become self-directed, lifelong learners (Brownell & Wood, 2021). This research suggests that metacognitive processes and metacognitive abilities such as learning, recognizing, and critical thinking skills must be enhanced because increased metacognitive processes or abilities are needed in many contexts.

The primary objective of the study was to create a model for the TPACK of the JHS in-service Science teachers based on the K-12 Curriculum and the Philippine Professional Standard for teachers. It is intended to formulate technological pedagogical content knowledge of science teachers in teaching 21st-century skills on metacognition in the classrooms. The second objective of the study was to determine the level of the TPACK of the science teachers in developing 21st-century metacognition among junior high school learners through a survey, and finally established the metacognitive model for the TPACK of JHS science teachers. The following questions were the focus of the investigation: (a)What is the TPACK of the science teachers in the junior high schools of Caraga considering the competencies of Ecosystem from G7-10? (b) How do the science teachers in the junior high schools of Caraga manifest TPACK for teaching metacognition to achieve the learning competencies in Ecosystem? and (c)What metacognitive model for the TPACK of science teachers may be established in teaching Ecosystem in junior high schools?

REVIEW OF LITERATURE

Metacognitive Construct

Metacognition is a powerful construct in today's educational setting. Flavell in 1979 first used the term 'metacognition'. It is defined as "cognition about cognition", or "knowing about knowing. Metacognition is the ability to self-regulate one's learning processes, encompassing the awareness of one's own cognitive strengths and limitations (Williams, 2019). It is the ability to plan and execute effective learning strategies, the capacity to monitor and evaluate one's progress, and the flexibility to adapt one's approach as needed (Padmanabha, 2020). Further, it encompasses the multifaceted ability to plan, monitor, regulate, and evaluate one's cognitive processes, allowing individuals to effectively navigate and manage their own learning experiences (Duman & Semerci, 2019).

Metacognition plays a pivotal role in intentional learning by fostering active engagement in the learning process, enabling individuals to critically assess their knowledge gaps, identify effective strategies for knowledge acquisition and application, and continuously refine their learning approach (Gönüllü & Artar, 2017. It can take many different forms, such as knowing when and how to apply specific learning or problem-solving strategy.

The main constituents of metacognition are "metacognitive knowledge and metacognitive experience or regulation. Metacognitive knowledge is not just about isolated components; it is about understanding how one's abilities, task demands, and strategy choices interact to influence learning and problem-solving success (Mahdavi, 2017). Metacognitive knowledge encompasses three distinct yet interconnected facets: declarative, procedural, and conditional knowledge. Effective coordination and application of these three types of knowledge significantly impact academic development and performance, as metacognition serves as a cornerstone for successful learning (Harris et al., 2018). Metacognitive knowledge can be added, deleted, or revised through metacognitive experiences.

Metacognitive experiences are the subjective feelings, thoughts, and experiences that arise during a cognitive task, providing individuals with insights into their own cognitive processes (Sun, Zhang, & Carter, 2021). These metacognitive experiences manifest as conscious cognitive or affective states, encompassing both intellectual and emotional dimensions, which accompany and inform one's engagement in various cognitive tasks (Dawson, 2018). Metacognitive knowledge and metacognitive experiences are intricately intertwined, forming partially overlapping sets that complement and enrich each other. To effectively cultivate a culture of metacognition within learners and classroom settings, a comprehensive approach should encompass both metacognitive knowledge acquisition and the development of metacognitive regulation skills (Perry & Golder, 2019).

Dawson (2018) mentioned that metacognitive skills encompass a multifaceted set of competencies that empower individuals to orchestrate their own cognitive processes effectively. These skills encompass self-awareness of one's cognitive strengths and limitations, the ability to plan and execute purposeful learning strategies, the capacity to monitor and evaluate one's progress, and the flexibility to adapt one's approach as needed. Metacognitive skills play a pivotal role in fostering active learning, critical thinking, reflective judgment, problem-solving, and decision-making, enabling individuals to navigate complex learning tasks and achieve their full potential.

Students with well-developed metacognitive skills are empowered to think critically, solve problems, and make decisions more effectively than those lacking these skills. From this perspective, metacognition is an essential element for successful learning, enabling individuals to self-regulate and direct their cognitive processes towards higher levels of understanding and achievement (Duhman & Semerci, 2019). Metacognition cultivates independent thinkers and lifelong learners who possess the self-regulatory skills to navigate the complexities of an ever-changing world (Commiso, 2019). By nurturing metacognitive abilities, individuals become adept at adapting to new situations, acquiring new knowledge, and continuously expanding their learning horizons (Blaschke & Hasse, 2016). This empowers them to thrive in a dynamic environment, embracing challenges and pursuing lifelong learning with confidence and resilience (Mahdavi, 2017).

Metacognition isn't just passive regulation, but an active and adaptable process of monitoring, analyzing, and adjusting cognitive strategies (Jaleel & Premachandran, 2016). Metacognitive skills are not just acquired, but actively developed, leading to significant learning transformations (Harris et al., 2019).

Metacognition, the ability to self-regulate one's learning, has emerged as a cornerstone of effective education. It encompasses the awareness and regulation of one's own thinking processes, allowing individuals to monitor, evaluate, and adapt their cognitive strategies to achieve desired learning outcomes.

One area of recent research on metacognition has focused on its neurocognitive basis. For example, Kuo et al. (2018) employed functional magnetic resonance imaging (fMRI) to investigate the neural underpinnings of metacognition during a visual working memory task. Their findings revealed heightened activation in brain regions associated with attention and executive control when participants engaged in self-monitoring of their performance compared to simply executing the task. These findings underscore the crucial role of attention and executive control in metacognitive processes. This suggests that metacognition involves specific neural processes that are distinct from those involved in task performance alone.

Recent research has also delved into the role of metacognition in online learning environments, shedding light on its significance in fostering effective self-regulation among online learners. For instance, Zhen et al. (2019) investigated the relationship between metacognitive awareness and self-regulated learning behaviors in an online course. Their findings revealed a positive association between metacognitive awareness and engagement in self-regulated learning strategies, such as goal setting, progress monitoring, and feedback seeking. These findings underscore the importance of cultivating metacognitive skills in online learning contexts, particularly where students have greater autonomy and responsibility for their learning trajectories.

Building upon these studies, recent research has also delved into the efficacy of metacognitive interventions in enhancing learning outcomes. For instance, Artino et al. (2017) meta-analysis investigated the impact of metacognitive training programs on academic performance across diverse educational settings. Their findings revealed that these interventions yielded moderate to substantial improvements in academic achievement. Furthermore, they demonstrated greater effectiveness when targeted towards specific metacognitive skills and delivered in a structured and scaffolded manner.

Metacognition training has been shown to positively impact students' personal perceptions of their learning progress, boosting their self-confidence, learning motivation, and self-efficacy. By incorporating metacognitive strategies into instruction, educators can foster students' problem-solving skills (Duhman & Semerci, 2019). Moreover, cultivating high metacognitive awareness among teachers is crucial for effectively developing metacognition in the classroom. Enhancing teachers' metacognitive levels empowers them to become more self-aware and reflective practitioners, leading to improved student learning outcomes (Slade et al., 2019). Metacognitive training enriches students' thinking, fostering a more dynamic and effective learning environment.

By enabling learners to understand their own cognitive processes, metacognitive strategies empower them to select and utilize appropriate learning tools to achieve their goals. This involves leveraging their awareness of individual learning preferences to effectively manage the cognitive demands of the learning process. Belet and Guven (2017) conducted a descriptive survey study to investigate the epistemological beliefs, the application of metacognitive strategy, and the relationship between these two aspects among primary education teacher trainees. The findings revealed that the most frequently employed metacognitive strategies by the trainees were self-control, cognitive strategy use, self-evaluation, and self-awareness, respectively. Alt (2017) investigated the association between constructivist-based educational approaches and the academic self-efficacy of higher education students. The study compared students enrolled in a Project-Based Learning (PBL) course to those in a lecture-based setting. Perceived constructivist pedagogical principles and outcomes revealed that PBL students thought that the educational setting was more constructivist and exhibited higher academic self-efficacy compared to their lecture-style counterparts.

Students driven to reflect and deeply explore concepts, as measured by high-order metacognitive engagement, demonstrated the strongest positive correlation with academic self-efficacy. Current educational trends emphasize student-centered learning and active knowledge construction as key levers for enhancing metacognition, contrasting with the passive knowledge reception of traditional teacher-led approaches (Duhman, 2017). Rico and Ertmer (2016) examined the role of instructors in student-centered approaches, particularly problem-centered ones, outlining effective strategies for facilitating meaningful discussions. Their findings highlight the value of metacognitive questioning, peer facilitation, and teacher training in fostering engaging and productive discussions.

Additionally, Perry and Golder (2019) emphasized the importance of recognizing and addressing individual differences in metacognitive awareness among students. They advocate for tailoring instruction to accommodate these differences, promoting the development of metacognitive abilities across the student population.

Metacognition plays a significant role in enhancing learning effectiveness, fostering long-term retention, and ultimately leading to improved student achievement. By engaging in metacognitive activities that encourage students to reflect on their knowledge, interests, and capabilities, educators can cultivate not only self-awareness but also valuable insights into students' learning processes. Jaleel and Premachandran (2018) emphasized the importance of nurturing metacognitive abilities among students, enabling them to critically evaluate their learning strategies, assess their performance in classroom activities, and make informed adjustments to optimize their academic outcomes.

Arslan's (2017) study identified and demonstrated a significant positive correlation between self-regulation and metacognition, suggesting that individuals with higher self-regulatory abilities tend to exhibit more advanced metacognitive skills and processes. This finding underscores the importance of fostering self-regulation in the classroom, as it serves as a foundation for developing metacognition. Embedded in the regular activities of a classroom, metacognitive activities that encourage reflection and strategic thinking can significantly enhance student learning outcomes. These activities should not be viewed as mere add-ons but rather as integral components of the learning process. By revealing the metacognitive skills used and helping students identify their preferred learning strategies; teachers can empower them to become lifelong learners beyond the classroom.

Metacognition empowers students to make informed choices about the most suitable learning strategies and tools for specific tasks, playing a pivotal role in successful learning (Wilson & Conyers, 2016). Moreover, metacognitive thinking serves as a cornerstone of effective knowledge transfer, enabling students to apply their learning across diverse contexts. The ongoing development of metacognitive skills is termed meta-learning (Drigas, Mitsea & Skianis, 2023).

Meta-teaching strategies can effectively mediate and stimulate students' metacognitive abilities, fostering their metacognitive thinking processes (Zhang et al., 2019). Therefore, educators should prioritize cultivating students' metacognitive awareness and identifying aspects that promote metacognitive development. Planning the learning process, assessing the process, and carrying out sufficient self-evaluation are all made possible by metacognitive awareness (Akben, 2020). Higher levels of learning achievement are associated with individuals who possess a great level of higher cognitive awareness, (Zhang et al., 2019) and self-directed learning skills (Karatas, 2017). Overall, recent research on metacognition has shed new light on the cognitive and neural processes underlying this construct, as well as its application in different educational contexts.

Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) is a conceptual framework that builds upon Shulman's (1986) study on Pedagogical Content Knowledge (PCK). Shulman posited that PCK is the cornerstone of effective teaching, enabling educators to transform disciplinary content into accessible and engaging learning experiences for their students. Effective pedagogy empowers teachers to curate, flex, and personalize subject matter, igniting the spark of learning in every student, regardless of students' background or learning style. Technological Pedagogical Content Knowledge (TPACK) stands as a comprehensive framework for effective teaching in the digital age. It builds upon the foundation of Shulman's Pedagogical Content Knowledge (PCK) concept, expanding it to encompass the integration of technology into teaching and learning.

TPACK is not merely a combination of separate knowledge domains; it represents a synergistic intertwining of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) (Dritts-Esser et al., 2017). Technological knowledge (TK) refers to the understanding of technology tools and applications, their capabilities, and their potential for enhancing teaching and learning (Santos & Castro, 2021). Pedagogical knowledge (PK) encompasses the knowledge of effective teaching strategies, learning theories, and instructional methodologies. Content knowledge (CK) denotes the deep understanding of the subject matter being taught, including its intricacies, connections, and real-world applications. TPACK emerges from the dynamic interplay of these three knowledge domains. It represents the skill to seamlessly incorporate technology into the process of teaching and learning, transforming subject matter content into engaging and accessible learning experiences for students (Joo et al., 2018). Effective TPACK practice involves selecting appropriate technology tools, designing technology-infused instructional activities, and assessing student learning outcomes in technologically enriched environments.

The TPACK framework has gained significant traction in the field of education, serving as a guiding principle for re-designing teacher preparation programs and professional development workshops (Chai et al., 2018). By equipping educators with the necessary knowledge and skills to effectively integrate technology into their teaching practices, TPACK empowers them to create dynamic and transformative learning experiences for their students.

Koehler and Mishra (2017) introduced the Technological Pedagogical Content Knowledge (TPCK) framework as a conceptual model for understanding the knowledge and skills required for effective technology integration in teaching. Participants in their research on the cooperative creation of online courses by master students and teacher education faculty gained a stronger comprehension of the intricate relationships that occur "between pedagogy", technology, and content in particular teaching situations. Based on these findings, directly quoted from the study of Koehler and Mishra (2017) "TPCK is a comprehensive framework for delineating the knowledge base necessary for teachers to effectively leverage technology in their teaching practices". Diverging from Niess and Gillow-Wiles (2017), Koehler and Mishra (2017) proposed TPCK not as an extension of PCK but as a distinct knowledge domain encompassing three interconnected components: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). This framework further delineates the intersections of these domains, giving rise to PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPCK itself.

However, the empirical validation of the TPACK framework's structure has encountered challenges. De Rossi and Trevisan (2018) employed exploratory factor analysis (EFA) and found difficulty in replicating Koehler and Mishra's original seven knowledge domains. This suggests that the TPACK framework, as conceptualized by Koehler and Mishra, may require further refinement and elaboration. This is further addressed in the section about measuring TPACK. Furthermore, Koehler and Mishra (2017) recognized that teaching with technology is not context-neutral but rather situated within the specific realities of the classroom, school, and broader educational environment. They emphasized the need for teachers to develop the flexibility to integrate their knowledge of students, the school's resources, and the available infrastructure into their pedagogical practices. In response to this contextual dimension, they incorporated context as an integral component of the TPACK framework, expanding it beyond the original seven knowledge domains. This contextualized TPACK framework has gained widespread recognition, offering a valuable lens through which to understand the potential contributions of emerging technologies to education. Furthermore, Koehler and Mishra acknowledged that as technology becomes increasingly integrated and transparent within educational practices, it seamlessly blends into PCK. This dynamic nature of TPACK led them to conceptualize it as a 'sliding framework,' emphasizing its adaptability to evolving technological landscapes (Voogt et al., 2018).

The transformative model of pedagogical content knowledge (PCK) proposed by Phillips et al. (2017), as cited by Hanuscin (2017), encompasses five interrelated components: (a) Orientations Toward Science Teaching-delves into the teacher's fundamental beliefs and philosophies about science education, encompassing their understanding of the nature of science, the role of inquiry, and the importance of student engagement; (b) Knowledge and Beliefs about Science Curriculum-focuses on the teacher's grasp of the science curriculum, including learning competencies, content standards, and performance standards. It encompasses their understanding of the curriculum's goals, objectives, and the rationale behind its design; (c) Knowledge and Beliefs about Students' Understanding of Specific Science Topics-highlights the teacher's understanding of students' cognitive development, their prior knowledge, and their potential misconceptions related to specific science topics. It emphasizes their ability to anticipate student difficulties and tailor instruction accordingly; (d) Knowledge and Beliefs about Assessment in Science- focuses on the teacher's understanding of assessment principles and practices in science education. It encompasses their ability to select, develop, and implement appropriate assessment tools to measure students' science learning effectively; and (e) Knowledge and Beliefs about Instructional Strategies for Teaching Science-centers on the teacher's repertoire of instructional strategies specifically designed for science education. It includes their understanding of subject-specific pedagogical approaches, laboratory techniques, and inquiry-based learning strategies.

Jimoyannis (2017) provided a comprehensive explanation of TPACK tailored to the specific domain of science education through the development of the Technological Pedagogical Science Knowledge (TPASK) framework. In this framework, TPASK represents the essential knowledge science teachers need to effectively include ICT (information and communication technology) into their instructional strategies. Jimoyannis (2017) distinguished three different types of knowledge:" technological science knowledge, pedagogical science knowledge, and technological pedagogical knowledge (TPK). The integration of these three knowledge domains is recognized by the TPASK framework as the fundamental component of successful technology integration in science education.

Koh (2017) employed the generate-evaluate-modify approach as a framework for organizing science teaching with technology. He demonstrates how pedagogy, encompassing teaching methods and teacher guidance, and technology, in the form of computer simulations, can be effectively combined to support students in various learning activities. These activities include compiling information, generating relationships between concepts, evaluating the validity of those relationships, and modifying their understanding based on the evaluation. Drawing from Jean Piaget's constructivist theory approach, Chai et al. (2018) emphasized the role of active knowledge construction in collaborative learning environments. They posited that learners actively construct knowledge through the interaction between their existing knowledge and experiences and the new information they encounter during the learning process."

Shulman's conceptualization of PCK acknowledged the role of technology in teaching, but it did not explicitly address the growing significance of technology in society and education. In response to this evolving landscape, Koehler and Mishra (2017) proposed the framework of TPCK, introducing knowledge of technology (TK) as a distinct knowledge domain alongside pedagogical content knowledge (PCK). TK encompasses a multifaceted understanding of technology, including conceptual knowledge of "digital technologies", procedural knowledge of their operation, and metacognitive knowledge of their effective integration into teaching practices (Laksana et al., 2019). This comprehensive knowledge base enables teachers to leverage technology effectively to enhance student learning and achieve both personal and professional goals (Vooght et al., 2018).

In the face of rapid technological advancements and the ever-evolving demands of globalization, Nuangchalerm (2017) aptly emphasized the need for effective teaching and learning processes that equip learners with the adaptability and skills to navigate this dynamic landscape. Research consistently underscores the pivotal role of teachers in shaping students' academic success, with Kaltakci (2017) highlighting their crucial influence on student achievement. Hanuscin et al. (2017) further reinforced this notion, emphasizing effective teachers as a critical factor in fostering student learning outcomes. Beyond simply possessing subject matter expertise and pedagogical knowledge, effective teachers must demonstrate the ability to seamlessly integrate these understandings into their teaching practices, empowering learners to conceptualize new ideas and engage in meaningful learning experiences (Agustini et al., 2019). Therefore, in order to equip students with a repertoire of abilities crucial in the workplace and in a knowledge-based society, instructors must be given the training and resources necessary to create technological pedagogical content knowledge (Nuangchalerm, 2017) in the teaching of science (Dep Ed Science K-12 Curriculum Guide, 2016).

Technological pedagogical content knowledge (TPACK), as conceptualized by Mishra and Koehler (2017), served as a comprehensive framework for understanding the knowledge base required for effective technology integration in teaching. Barton and Dexter (2020) employed TPACK to define a teacher's technology integration proficiency. The framework encompasses technological knowledge (TK) as an integral component of a teacher's professional expertise (Voogt et al., 2018). Chai et al. (2018) proposed TPACK as an appropriate framework to bridge the gap between teacher education and educational technology, suggesting its applicability to content-driven science instruction. Lu and Hsu (2019) emphasized TPACK's ability to provide a holistic understanding of using technology into instruction and learning, particularly in science education. Wang and Chen (2020) study revealed a direct relationship between TPACK levels and teachers' effective use of technology to enhance student learning outcomes in mathematics. Similarly, another study demonstrated that teacher education programs incorporating TPACK training are more effective in preparing pre-service teachers to seamlessly integrate technology into their teaching practices (Hu & Lin, 2021).

In the 21st century technology-driven educational landscape, those that teach science with success are those who can effectively leverage information and communication technologies (ICTs) to create suitable pedagogical methods and representations of scientific knowledge, fostering fruitful learning experiences (Chai et al., 2018). The TPACK framework, as proposed by Park and Lim (2018), offered a valuable tool for teachers to deepen their understanding of how technology can be purposefully integrated into their teaching practices to increase interest and involvement among students, particularly in language learning. Karadeniz and Akkoyunlu (2019) study further underscored how well TPACK-based professional development programs work to give teachers the tools they need to successfully incorporate technology into their teaching techniques, which improves student results. It is for modern-day teachers to possess a comprehensive understanding of subject matter knowledge, knowledge of technology, and knowledge of pedagogy, recognizing the interconnectedness of these domains in effective teaching with technology.

THEORETICAL AND CONCEPTUAL FRAMEWORK

The study is anchored on some theories that cited the relevance of the Hierarchical model of the Metacognitive Technological Pedagogical and Content Knowledge (TPACK) of Science Teachers through Formative Measurement.

Jerome Bruner's constructivist theory offers a powerful lens through which to view instruction, rooted in the science of learning. Its core principle is that learning thrives as an active, investigative journey. Individuals weave new information into the tapestry of their existing knowledge and experiences, constructing their unique understanding of the world. This theory, deeply rooted in cognitive psychology, revolutionized educational practices by emphasizing the learner's central role in the construction of knowledge. It advocates for an active learning approach, where learners are not passive recipients of information but rather engaged participants in the learning process. They actively select, transform, and interpret information, constructing hypotheses and making decisions based on their cognitive frameworks.

Bruner's spiral curriculum model emphasizes the importance of revisiting and building upon core concepts throughout the learning journey. This approach ensures that learners gain a comprehensive understanding of concepts, progressively refining their knowledge as they advance. Constructivism has significantly impacted science education, highlighting the importance of addressing students' mental models and misconceptions. Teachers can effectively model scientific reasoning by acknowledging and addressing students' preconceptions, fostering conceptual change and promoting deeper understanding.

Experiential learning, rooted in the notion of "learning by doing," emphasizes the significance of practical, real-world experiences that actively engage learners. Through hands-on activities, learners are challenged to think critically, confront complex problems, and reflect deeply on their learning. Both constructivism and experiential learning underscore the importance of active engagement and the creation of personal meaning, which are fundamental pillars of lifelong learning. Lifelong learning, an ongoing pursuit of knowledge and skill acquisition, is essential for personal and professional growth in an ever-evolving world. By engaging learners in active, hands-on experiences that foster critical thinking, problem-solving, reflection, constructivism, and experiential learning, we establish a blueprint for lifelong learning, empowering individuals to navigate the complexities of a dynamic world.

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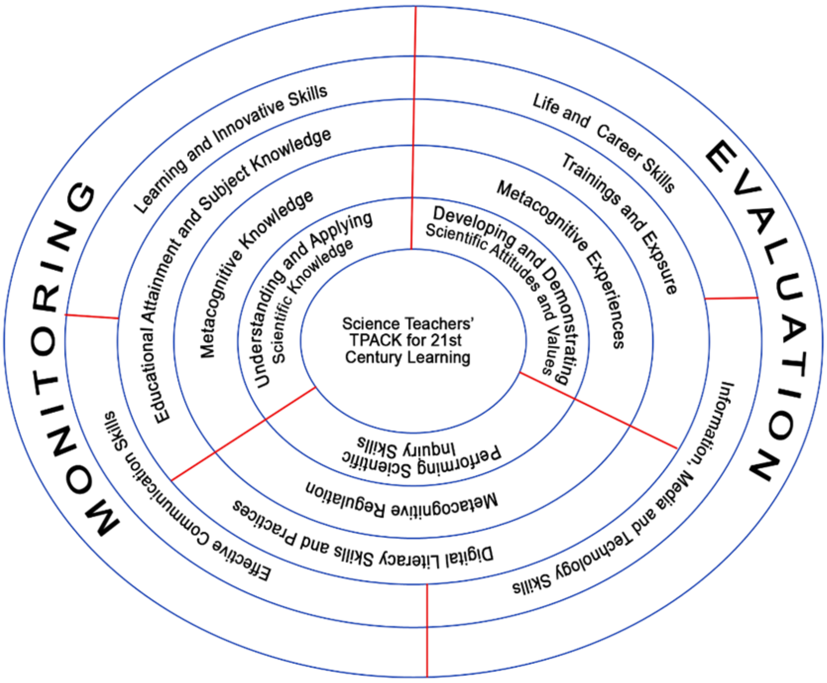

Figure 1: Research Paradigm for the development of the Metacognitive Model of Science Teachers' TPACK

The study was focused on identifying the TPACK of the science teachers in developing 21st-century metacognition among junior high school learners. It established the metacognitive model for the TPACK of JHS science teachers in teaching Ecosystem in the Junior High School using Spiraling Progression. Figure 1 showed the different concentric circles that revolve around Science Teachers TPACK for 21st Century Learning.

Various concepts were identified as key variables for the development of the metacognitive model of Science Teachers' TPACK. How these concepts were viewed and understood was dependent on the disciplinary core ideas of teaching Science. The disciplinary core ideas include Understanding and Applying Scientific Knowledge, Developing and Demonstrating Scientific Attitudes and Values, Performing Scientific Inquiry Skills, and the types of metacognition or processes namely Metacognitive Knowledge, Metacognitive Experiences, and Metacognitive Regulation. The types of metacognition encompassed teachers' educational attainment and subject knowledge, teachers pieces of training and exposure, digital literacy skills and practices of the teachers. All of these were monitored and evaluated to enhance and develop the enduring 21st century learning skills of the students which are effective communication skills, learning and innovative skills, life and career skills, and ICT skills.

The presented body of literature and the interconnected theoretical frameworks of constructivism, and experiential learning theory underscore the undeniable significance of these connecting factors in unlocking students' potential in the digital age. These theories play a pivotal role in creating a plan for education in the future, encompassing prevailing learning from early education to ongoing professional development and fostering civic engagement. By aligning education with the demands of the Fourth Industrial Revolution, these interconnected theories pave the way for the future of education that is adaptable, transformative, and empowering.

METHODS AND MATERIALS

Research Design

This study employed descriptive-correlational design. It determined and explained the relationship of the variables involved in the study such as levels of CK. PK, and TK of the Junior High School Science teachers, and the types of metacognitive strategies applied by the teachers in the classroom without making any claims about cause and effect. The aforementioned variables were measured and the patterns and relationships that emerged from the data were identified.

Research Instruments

The study used two kinds of research instruments. The first research instrument was the TPACK survey designed by (Deng et al., 2017). It was used with some modifications to analyze the PK (Pedagogical Knowledge), TK (Technological Knowledge), and TPACK (Technological Pedagogical Content Knowledge in line with the PPST (Philippine Professional Standards for Teachers) domains such as content and pedagogy, learner's diversity, learning environment, and assessment. Included in the survey questionnaire are the metacognitive strategies or activities employed by the in-service JHS Science teachers namely metacognitive close reading exercise, reflection questions, inking your thinking, monitoring strategy (alarm clock), and evaluation strategy (connecting elephants). The rubric was prepared and designed as a scheme for giving points to teachers. Its purpose was to identify the level of TPCK among teachers who were involved in the study.

The first research instrument was made up of two parts. The first part was about the profile of the teacher participants which included the name (optional), Sex. Age, Specialization, Highest educational attainment, and training attended. The second part was the actual survey questionnaire which contained the three types of knowledge namely Pedagogical Knowledge (PK), Technological Knowledge (TK), and Technological Pedagogical Content Knowledge (TPACK). The Pedagogical Knowledge (PK), the Technological Knowledge (TK), and the Technological Pedagogical Content Knowledge (TPACK) questionnaires had 12 items respectively. All items were categorized into four PPST domains. In line with the 36 TPACK- items, the teachers identified the metacognitive strategies that they employed in teaching Ecosystem in terms of Content and Pedagogy, Learner's Diversity, Learning Environment, and Assessment.

The second research instrument was the 60-item Test Questionnaire (TQ) together with its Table of Specifications (TOS) for the 12 competencies of Ecosystem from the Grades 7-10 Curriculum Guide. The TOS and TQ were constructed to measure the Content Knowledge of the JHS Science teacher participants. The 60-item TQ was comprised of two parts. The first part is Multiple Choice in which there were options given for each number. The second part is the Constructed Response/Essay for questions that involve analysis by which the teacher participant explained his/her answer briefly based on the given question. Based on the given learning competencies, the 60 item test questions were categorized based on the types of metacognition namely metacognitive knowledge, metacognitive experience, and metacognitive regulation.

Population and Sampling

The participants involved in the study were 70 JHS Science teachers handling different year levels from Grades 7-10 in the identified public and private Junior High Schools in Butuan City. Cochran formula was used to get the required sample size.

This study employed both non-probability and probability sampling in which the teacher participants were given equal chance to be part of the study based on specific criteria. The teacher participants were chosen through simple random sampling. The teacher participants were JHS Science teachers who are teaching at any grade level in the Junior High school. In the same manner, the Junior High Schools were chosen purposively. The identified Public secondary schools must be empowered, and the chosen private schools must have a Junior High School student population of more than three hundred (300).

Analysis and Treatment

The study used quantitative analysis of the data. The responses of the teacher participants on the level of technological, pedagogical, and content knowledge were assessed using the scale shown below:

Level of Technological Pedagogical Content Knowledge

Table 1. Scale assigned to the responses of the participants on the level of the three types of knowledge

Responses	**Value**	**Range**	**Interpretation**
Strongly Agree	**5**	4.50-5.00	Very High
Agree	**4**	3.50-4.49	High
Neutral	**3**	2.50-3.49	Moderate
Disagree	**2**	1.50-2.49	Low
Strongly Disagree	**1**	1.00 -1.49	Very Low

Data that were gathered in this study were statistically treated using descriptive and inferential statistics such as frequency and percentages, mean, Pearson Product Correlation, and Structural Equation Modeling.

RESULTS AND DISCUSSION

This part of the paper presents the discussion on the analysis and interpretation of data in tables and figures.

JHS Science Teachers TPACK for teaching metacognition

Table 2 shows the mean ratings of the JHS Science Teachers' Technological Pedagogical Knowledge and Content Knowledge (TPACK). The overall mean rating is 4.28, which indicates that the JHS Science Teachers have a high level of TPACK. This is supported by the fact that all of the individual items have mean ratings of above 4.19. The JHS Science Teachers have the highest level of TPACK in the following areas namely Learning Environment (4.33), and Assessment (4.34) as compared to Content and Pedagogy (4.25) and Learners Diversity (4.23). The high overall mean rating for TPACK indicates that the JHS Science Teachers have a strong understanding of how to use content, pedagogy, and technology to teach science effectively. The JHS Science teachers are able to select and use content, pedagogy, and technology to enhance their teaching, assess student learning, and create a positive learning environment. However, the slightly lower mean ratings for Content & Pedagogy and Learners' Diversity as compared to other domains indicate that there are some areas where the JHS Science Teachers could improve their TPACK. The Science teachers could focus on developing more lessons regarding Ecosystem that combine science, technology, and teaching approaches in a meaningful way. This could involve using content, pedagogy, and technology to help students learn and apply scientific concepts pertaining to Ecosystem, or to develop learners' critical thinking and problem-solving abilities.

Table 2: Level of Technological Pedagogical Knowledge and Content Knowledge (TPaCK)

Knowledge		
Content & Pedagogy	4.25	High
Experience		
Learners' Diversity	4.23	High
Learning Environment	4.33	High

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Reflection		
Assessment	4.34	High
Overall Mean	**4.29**	**High**

Description: 1.00-1.49: Very low, 1.50-2.49: Low, 2.50-3.49: Moderate, 3.50-4.49: High & 4.50-5.00: Very high

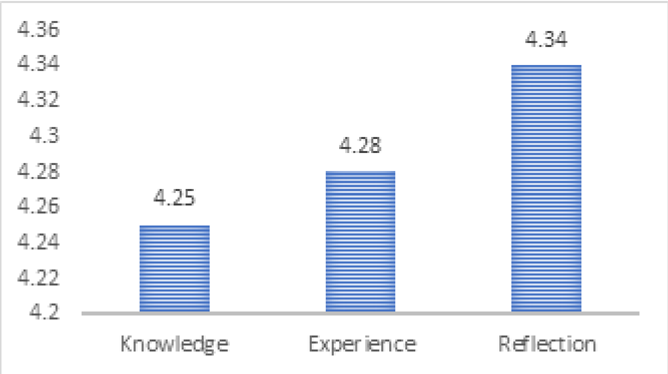
Table 2A: Mean Ratings of the JHS Science Teachers' Technological Pedagogical Knowledge and Content Knowledge (TPACK)

Knowledge		
Content & Pedagogy		
1. I can teach lessons that appropriately combine science, technologies, and teaching approaches	4.33	Agree
2. I can facilitate the integration of curriculum areas to construct multidisciplinary knowledge.	4.19	Agree
3. I can engage in sustained involvement with curriculum activities.	4.22	Agree
Learners' Diversity		
4. I can select effective teaching approaches and appropriate technologies to guide student thinking and learning in Science.	4.22	Agree
5. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/ or district.	4.19	Agree
6. I can choose content, pedagogical strategies, and varied technologies that are relevant and engaging for the students.	4.28	Agree
Learning Environment		
7.I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom.	4.35	Agree
8. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.	4.36	Agree
9. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom	4.28	Agree
Assessment		
10. I can undertake formative and/or summative assessments	4.49	Agree
11. I can critically evaluate students' own and society's values.	4.26	Agree
12. I can critically interpret and evaluate the worth of ICT-based content for specific subjects	4.28	Agree

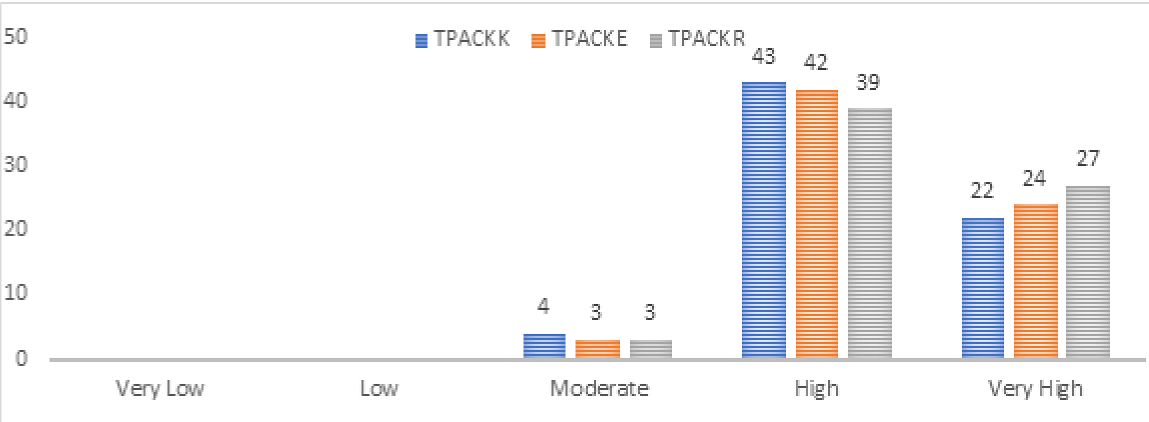
Description: 1.00-1.49 (Very Low); 1.50-2.49 (Low), 2.50-3.49 (Moderate). 3.50-4.49 (High), 4.50-5.00 (Very High)

The teachers could also focus on developing more effective teaching approaches and technologies to guide student thinking and learning in Science specifically on the unit topic Ecosystem, for students with diverse needs. This could involve using content, pedagogy, and technology to provide students with personalized learning experiences, or to provide support for students who are struggling.

Numerous studies have examined the importance of TPACK in the context of science education. For instance, Mishra and Koehler proposed the TPACK framework as a way to conceptualize effective teaching with technology. They highlighted the necessity for educators to integrate their knowledge of technology, pedagogy, and content to successfully engage students in meaningful learning experiences (Drummond & Sweeney, 2017). Research has shown that science teachers with strong TPACK are better equipped to create dynamic and interactive learning environments. One study by Aktas and Ozmen (2020) found that integrating technology into science instruction improved students' understanding of complex scientific concepts and enhanced their motivation and engagement. Additionally, a study by Barak (2017) demonstrated that when teachers effectively integrate technology into their science teaching, students develop a deeper understanding of scientific concepts and are better prepared to apply their knowledge in real-world contexts. Furthermore, research by Turner (2020) indicated that JHS science teachers with a strong TPACK were better equipped to design and implement technology-enhanced lessons that effectively conveyed complex scientific concepts. This demonstrates the relevance of TPACK for enhancing the quality of science education at the junior high school level.



[A] Mean ratings of JHS teachers TPACK across metacognitive components



[B] Frequency distribution of JHS teachers in TPACK across metacognitive components (n=70)

Description: 1.00-1.49 (Very Low); 1.50-2.49 (Low), 2.50-3.49 (Moderate). 3.50-4.49 (High), 4.50-5.00 (Very High)

Legend: TPACKK- Knowledge in TPACKK, TPACKE – Experience in TPACK, TPACKR – Reflection in TPACK

Figure 2: Level of Technological Pedagogical and Content (TPACK) Knowledge across Metacognitive Components

The results depicted in Figure 2 illustrate the varying levels of Technological Pedagogical and Content Knowledge (TPACK) across metacognitive components. The graph displays that the mean ratings for knowledge, experience, and reflection are all above 4, indicating a high level of TPACK across all metacognitive components. It also shows that there is some variation in TPACK levels across different metacognitive components. The mean rating for knowledge is highest for the TRACKK component (4.37), followed by TPACKE (4.29) and TPACKR (4.24). The mean rating for experience is highest for the TPACKE component (4.34), followed by TRACKK (4.32) and TPACKR (4.27). The mean rating for reflection is highest for the TPACKE component (4.40), followed by TRACKK (4.39) and TPACKR (4.33). To elaborate, the TRACKK component of TPACK signifies the adept use of technology, content, and pedagogy to craft engaging learning experiences for all students. On the other hand, the TPACKE component focuses on employing JHS science teachers' experiences of technology, content, and pedagogy to assess and evaluate student learning, while the TPACKR component emphasizes the ability to reflect on and enhance teaching practices. The fact that the teachers of science possess a high degree of TPACK. across all metacognitive components suggests that they are able to use content, pedagogy, and technology effectively to teach all students, regardless of their background. This is important because it helps to ensure that all students have an equal opportunity to learn and succeed. However, the observed variations in TPACK levels across different metacognitive components suggest potential areas for targeted support and professional development. Specifically, the data imply that the Science teachers might benefit from additional training, particularly in areas related to catering for students with specific needs. This further training can enhance their ability to employ content, pedagogy, and technology effectively, ensuring inclusive and tailored educational experiences for all students.

The data in table 3 show that teachers are using a variety of metacognitive strategies to manage their TPACK. Specifically, the data show the percentages of teachers who use various metacognitive strategies manifesting their technological pedagogical knowledge and content knowledge (TPACK). The most commonly used metacognitive strategies are close reading, and reflection question. These strategies are all related to the ability to think about one's own thinking and to learn from experience.

Table 3: Metacognitive Strategies Manifesting the Technological Pedagogical Knowledge and Content Knowledge (TPACK) of JHS Science Teachers

Parameters	**A. Metacognitive "Close Reading" Exercise**		**B. Reflection Question**		**C. Inking Your Thinking**		**D. Monitoring Strategy**		**E. Evaluation Strategy (Connecting Elephants)**	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
Knowledge										
Content & Pedagogy	59	**84.3**	43	**61.4**	22	31.4	18	25.7	17	24.3
Learning Environment	53	**75.7**	30	42.9	18	25.7	10	14.3	9	12.9
Experience										
Learners' Diversity	56	**80.0**	37	**52.9**	25	35.7	20	28.6	12	17.1
Reflection										
Assessment	28	40.0	38	**54.3**	28	40.0	20	28.6	16	22.9

The least commonly used metacognitive strategies are evaluation strategy (connecting elephants) and monitoring strategy. These strategies are related to the ability to compare and contrast different concepts and ideas, and to monitor one's own learning process. The data imply that the JHS science teachers understand the significance of metacognition in teaching and learning Science specifically on the unit topic Ecosystem.

Metacognitive strategies can help students to develop their own critical thinking skills and to become more self-directed learners. However, the limited utilization of metacognitive strategies involving the ability to compare and contrast different concepts and ideas and to monitor one's own learning process indicates potential areas where JHS science teachers might benefit from additional support. This suggests an opportunity for targeted training initiatives, enabling teachers to adeptly employ metacognitive strategies. The training could empower the JHS Science teachers to guide students in honing students' critical thinking abilities and nurturing self-directed learning, thereby enriching the overall teaching and learning experience.

Metacognitive model for the TPACK of JHS science teachers

The estimates indicate the strength and direction of the relationships between the predictor latent variables and the outcome latent variable (TPACK Latent). The estimate of 0.2704 indicates that there is a positive relationship between TPACK Latent and PK Latent. A one-unit increase in PK Latent is associated with a 0.2704 unit increase in TPACK Latent. This implies that the JHS Science teachers with higher levels of pedagogical knowledge (PK) are also more likely to have higher levels of technological pedagogical and content knowledge. However, since the p-value is 0.173, the relationship is not statistically significant at the conventional significance level of 0.05. The confidence intervals (-0.119 to 0.6593) indicate the range within which we can be 95 confident that the true population parameter lies. In a similar vein, the estimate of 0.8591 indicates that there is a strong positive relationship between TPACK Latent and TK Latent. A one-unit increase in TK Latent is associated with a 0.8591 unit increase in TPACK Latent. This indicates that the JHS Science teachers with higher levels of technological knowledge (TK) are also more likely to have higher levels of technological pedagogical and content knowledge. The p-value of < .001 indicates that the relationship is statistically significant at the conventional significance level of 0.05. The confidence intervals (0.411 to 1.3077) indicate the range within which we can be 95 confident that the true population parameter lies. On the other hand, the estimate of -0.0562 indicates that there is a negative relationship between TPACK Latent and CK Latent. However, the magnitude of the relationship is small, as a one-unit increase in CK Latent is associated with only a -0.0562 unit decrease in TPACK Latent. Moreover, since the p-value is 0.110, the relationship is not statistically significant at the conventional significance level of 0.05. The confidence intervals (-0.125 to 0.0127) indicate the range within which we can be 95 confident that the true population parameter lies.

Data presented in Figure 3 suggests a positive trend between TPACK and PK, although the correlation doesn't reach statistical significance. In addition, there's a clear and substantial positive correlation between these two key components of effective teaching. Nevertheless, there exists a slight inverse correlation between TPACK and CK, but the relationship is not statistically significant. In other words, the more knowledge a teacher has about pedagogy and technology, the more likely they are to have TPACK. In accordance to the results, Chai et al., (2018) stated that TPACK is not a unique body of knowledge, but is a simple combination of TK, PK, and CK that existed in the teaching arena. This implies that both (TK and CK) are likely assessing related areas of TPACK. Knowledge of technology and pedagogy could not be isolated from TPACK. Further, in order to create a more comprehensive picture of instructors' TPACK, Drummond and Sweeney (2017) proposed that objective indices of technological pedagogical and content knowledge may be added to the content knowledge measured by TPACK scales. However, it does not appear that a teacher's TPACK has a significant impact by the quantity of content knowledge they possess. In their study, Greene and Jones (2020) discovered that although content knowledge is essential for effective teaching, a teacher's capacity to use technology in the classroom may not be directly correlated with it. Moreso , to effectively use technology in the classroom, teachers must gain the flexibility to include information about the learners, the school, the existing infrastructure, and the surrounding environment (Kohler & Misra, 2017). The results of this study have important implications for the programs for professional development and teacher education. The findings suggest that the teachers ought to concentrate on developing teachers' technical knowledge, as this is strongly associated with teachers' technological

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pedagogical and content knowledge. Additionally, teacher educators may consider developing teachers' pedagogical knowledge, as this may also be associated with teachers' technological pedagogical and content knowledge.

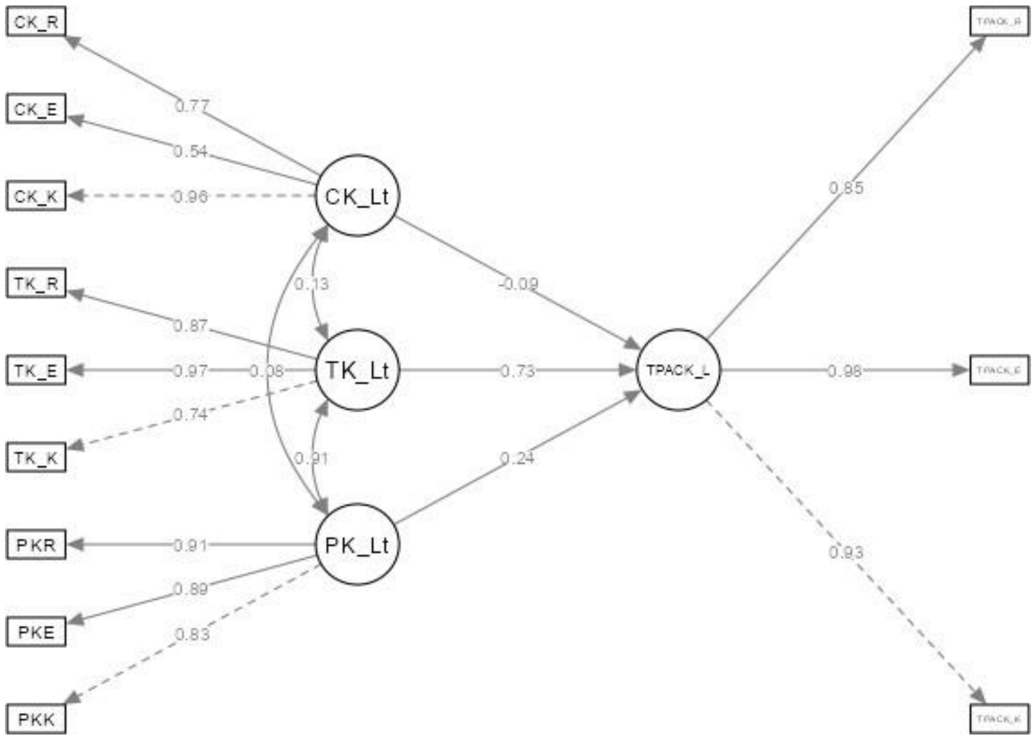

Figure 3: Formative Model of the Metacognitive Technological Pedagogical and Content Knowledge (TPACK)

Figure 3 also manifests that all of the path coefficients are significant, which means that there is a statistically significant relationship between the latent variables and their observed variables. The observed variables PK K, PK E, and PK R all load highly on the PK Latent latent variable, indicating that they are all good measures of pedagogical knowledge. The observed variables TK K, TK E, and TK R all load highly on the TK Latent latent variable, indicating that they are all good measures of technological knowledge. The observed variables CK K and CK R both load highly on the CK Latent latent variable, but CK E does not load significantly on the latent variable. This suggests that CK E is not a good measure of content knowledge. Lu and Hsu (2019) mentioned that TPACK provides a comprehensive understanding of how pedagogy and technology can be effectively incorporated into the process of teaching and learning particularly in science education. Results indicated that teachers were more likely to demonstrate high-level TPACK when they were proficient in managing the three metacognitive processing skills monitoring, evaluation, and planning. Hence, the metacognitive indicators in the formative model would aid in the development of TPACK.

Table 4: Measurement model of TPACK Latent Variable 95 Confidence Intervals

Latent	**Observed**	**Estimate**	**SE**	**Lower**	**Upper**	**β**	**z**	**p**
PK Latent	PKK	1.000	0.0000	1.000	1.00	0.828		
	PKE	1.006	0.1075	0.796	1.22	0.892	9.36	< .001
	PKR	1.051	0.1083	0.839	1.26	0.912	9.70	< .001
TK Latent	TK K	1.000	0.0000	1.000	1.00	0.744		
	TK E	1.299	0.1503	1.004	1.59	0.969	8.64	< .001

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	TK R	1.329	0.1725	0.991	1.67	0.874	7.70	< .001
CK Latent	CK K	1.000	0.0000	1.000	1.00	0.960		
	CK E	0.763	0.1829	0.404	1.12	0.540	4.17	< .001
	CK R	0.898	0.1646	0.576	1.22	0.774	5.46	< .001
TPACK Latent	TPACK K	1.000	0.0000	1.000	1.00	0.932		
	TPACK E	1.091	0.0620	0.969	1.21	0.976	17.58	< .001
	TPACK_R	0.919	0.0815	0.759	1.08	0.854	11.27	< .001

For the PK Latent latent variable, PKK serves as the reference category with a beta coefficient of 1.000, indicating that there is no change in the outcome variable when PKK is compared to itself (since it's the reference category). For PKE, the beta coefficient is 1.006, which means that a one-standard deviation increase in PKE is associated with a 1.006 standard deviation increase in the outcome variable. Similarly, for PKR, the beta coefficient is 1.051, indicating that a one-standard deviation increase in PKR is associated with a 1.051 standard deviation increase in the outcome variable. All variables have a strong positive relationship between the latent variable with beta value greater than 0 and close to 1. This relationship holds statistical significance with a p-value of 0.001.

In parallel, for the TK Latent latent variable, TK K serves as the reference category with a beta coefficient of 1.000, indicating no change in the outcome variable when TK K is compared to itself (since it's the reference category). For TK E, the beta coefficient is 1.299, meaning that a one-standard deviation increased in TK E is associated with a 1.299 standard deviation increase in the outcome variable. Similarly, for TK R, the beta coefficient is 1.329, indicating that a one-standard deviation increased in TK R is associated with a 1.329 standard deviation increase in the outcome variable. All variables have a strong positive relationship between the latent variable with beta value greater than 0 and close to 1. This relationship is statistically significant with a p-value of 0.001(Note: with TKK as reference TKE affects the latent variable than TKK with an estimate of 1.299 and a CI (1.004-1.59) which is Significant since CI did not include the value 1.00).

For the CK Latent latent variable, CK K serves as the reference category with a beta coefficient of 1.000, indicating no change in the outcome variable when CK K is compared to itself (since it's the reference category). For CK E, the beta coefficient is 0.763, indicating that a one-standard deviation increased in CK E is associated with a 0.763 standard deviation increase in the outcome variable. Similarly, for CK R, the beta coefficient is 0.898, meaning that a one-standard deviation increased in CK R is associated with a 0.898 standard deviation increase in the outcome variable. All variables have a strong positive relationship between the latent variable with beta value greater than 0 and close to 1. There is a statistical significance in this relationship with a p-value of 0.001.

For the TPACK Latent latent variable, TPACK K serves as the reference category with a beta coefficient of 1.000, indicating no change in the outcome variable when TPACK K is compared to itself (since it's the reference category). For TPACK E, the beta coefficient is 1.091, meaning that a one-standard deviation increased in TPACK E is associated with a 1.091 standard deviation increase in the outcome variable. Similarly, for TPACK R, the beta coefficient is 0.919, indicating that a one-standard deviation increased in TPACK_R is associated with a 0.919 standard deviation increase in the outcome variable. All variables have a strong positive relationship between the latent variable with beta value greater than 0 and close to 1. There is a statistically significant correlation in this relationship with a p-value of 0.001.

The data in table 4 illustrate that there is a strong positive relationship between all of the latent variables (PK Latent, TK Latent, CK Latent, and TPACK Latent). This means that a one-unit increase in any latent variable is associated with a one-unit increase in the other latent variables. Further, the relationships between the latent variables are statistically significant, with p-values of 0.001 for all four relationships. This means that the more knowledge a teacher has about pedagogy, technology, content, and TPACK, the more likely they are to have knowledge about the other three areas. On top of it, the relationships between the latent variables are strong and statistically significant, which suggests that they are all important components of teacher knowledge. Although, the estimated differences between the latent variables are not significant, which means that it can't be determined which latent variable contributes more to the other latent variables. This means that the results are very likely not due to chance. A teacher with strong TPACK has the capacity to create and implement successful learning encounters that integrate pedagogy, technology, and content. The results suggest that all four areas of teacher knowledge are important for effective teaching. These findings also suggest that the four latent variables are all important components of teacher TPACK. Teachers who have more knowledge about pedagogy, technology, content, and TPACK are more likely to have knowledge about the other three areas. This is because these areas are all interconnected. However, more research is needed to understand the specific mechanisms by which these relationships work and to develop effective strategies for improving teacher knowledge in all four areas.

CONCLUSIONS

The teachers possess a strong proficiency of TPACK, particularly in the areas of Learning Environment and Assessment, but could improve in Content & Pedagogy and Learners' Diversity. The JHS Science teachers implement metacognitive strategies to manage their TPACK, but could benefit from additional support in comparing and contrasting concepts and monitoring the learning process. The measurement model showed that the latent variables are well-measured by their observed variables. Thus, in the formative model, the metacognitive indicators would aid in the development of TPACK. Administrators may focus on developing teachers' TK, PK, and metacognitive processing skills to enhance their TPACK and teaching effectiveness.

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