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Teachers' Technological Pedagogical and Content Knowledge (TPACK) Competence and Technology Integration Self-Efficacy Beliefs for Science Teaching

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Abstract. This study investigates the level of TPACK competence and technology integration self-efficacy beliefs among junior and senior high school science teachers of Ifugao. While existing research has explored TPACK and self-efficacy in general educational contexts, there is a notable gap in understanding the TPACK competence and technology integration self-efficacy beliefs among science teachers in junior and senior high schools of Ifugao. Using a descriptive-correlational research design, a 4-point modified Likert scale survey questionnaire was employed to gather necessary data from randomly selected one hundred (100) junior and senior high school science teachers in Ifugao. Pearson r, t-test, and ANOVA with Scheffe's Post-Hoc test were employed to test null hypotheses. Results showed that teachers had demonstrated proficiency in leveraging technology to enhance student engagement and learning outcomes, as evidenced by their experience with TPACK competencies. On the other hand, their technology integration self-efficacy belief was at an expert level, indicating a high level of self-assurance in integrating technology, adapting pedagogical approaches, and delivering science lessons using various digital tools. Additionally, the findings suggest a strong correlation between science teachers' TPACK competence and their self-efficacy beliefs regarding technology integration. Younger science teachers show higher Technological Content Knowledge (TCK) competence than older age groups. The number of training sessions or seminars attended has been proven to be a crucial factor influencing competence in TPACK, technology integration, and self-efficacy beliefs. The results contribute to the growing body of research on TPACK and self-efficacy, highlighting the importance of supporting science teachers in developing their technological, pedagogical, and content knowledge to enhance student learning outcomes. This provides insights into the current state of technology integration in science education in Ifugao and informs recommendations for teacher professional development and educational policy.

Keywords: Content knowledge; Technology integration; Teachers' TPACK; Training attended; Self-efficacy beliefs.

1.0 Introduction

Science education in the modern age relies heavily on technology, enhancing teachers' and students' understanding of scientific theories and concepts. Technology integration in science teaching fosters improved comprehension, critical thinking, and interactive learning, enabling students to engage effectively with scientific practices. As scientific knowledge evolves rapidly, pedagogical strategies must transform continuously to make science relevant to teachers' and learners' lives. The key factors for successful integration are science teachers' Technological, Pedagogical and Content Knowledge [TPACK] (Koehler et al., 2014; Koehler et al., 2013), and technology integration self-efficacy beliefs. These facilitate effective technology use, contextualized learning, and innovative teaching approaches. However, limited studies have addressed improving teachers' TPACK competence and technology integration self-efficacy, especially in Ifugao's junior and senior high schools. Thus, this study aims to fill this gap by investigating the factors influencing teachers' TPACK competence and technology integration self-efficacy beliefs in science education within the Ifugao context. By analyzing the current state of technology integration in Ifugao schools, this study aims to adapt education to modern trends, enhance pedagogical approaches through the use of technology, develop targeted professional development programs, and ensure that students receive an extensive, technology-enriched science education.

To meet the needs of *new-digital-era* learners and improve learning effectiveness, science educators need to develop creative approaches that involve students of differing interests, skills, and experiences. After all, the quality of science education is closely tied to teachers' content knowledge of the subject, their pedagogical approaches, and their ability to effectively apply these with technology (Cordova & Linaugo, 2022). Effective science teachers should be self-reflective, collaborative, and committed to ongoing learning. Unfortunately, science education in the Philippines has relied profoundly on teacher-centered instructional methods. Science educators may lack the necessary knowledge and pedagogical skills to make science engaging and relevant. This approach might lead to learning focused on textbooks and result in memorization without a deep understanding of the content. The lecture-based approach continues to be employed, considering students as *"empty vessels"* and passively imparting knowledge. Applying this method, Student interests, exploration, and inquiry are suppressed (SEI-DOST & UP NISMED, 2011, *p. 6*). As a result, students perceived that science topics like Chemistry and Physics are irrelevant and discouraging because they are often presented with a heavy emphasis on abstract concepts and complex formulas (Turno, 2020). This is one of the reasons for the decline in the Philippines' mean score in science by one point in 2022 compared to 2018 Programme for International Student Assessment (PISA) result, which led the country to rank 78th out of 80 participating countries (Organization for Economic Co-operation and Development [OECD], 2023).

To adapt these mainstream pedagogical strategies, teachers should seize the opportunity to utilize emerging technological advancements in science education as supplementary tools to fully implement the combination of Technological, Pedagogical, and Content Knowledge (TPACK) in teaching science. Though science educators have mastered the content of their subjects and are executing their teaching strategies effectively, they need to consider the interests and learning styles of the digital generation learners. SEI-DOST & UP NISMED (2011) emphasized that an effective science teacher understands the variety of technology and other resources, and how to incorporate them into new learning experiences that make learners confident and proficient technology users. With this, science educators should be competent in utilizing various technologies and pedagogies to enhance their teaching and help students understand and appreciate science.

TPACK competence specifies the knowledge a teacher needs to integrate technology, innovate pedagogy, and provide appropriate science content to enhance student learning (UNESCO ICT CFT, 2023; Koehler & Mishra, 2009; Mishra, 2019; Irwanto, 2021). These studies provide comprehensive guidelines for teachers to develop the necessary competencies to enhance student learning through innovative technology in pedagogy and content delivery. Specifically, technological Knowledge (TK) in the teaching-learning process is crucial in today's digital era (Agustini et al., 2019); therefore, educators need to be supported in incorporating components of content and pedagogical knowledge with technology. Moreno (2015) emphasizes that integrating technology into teaching methodologies enhances student engagement, fosters interactive learning environments, and equips learners with essential 21st-century skills.

Drawing on the study of Yusuf & Balogun (2011), effective technology integration requires teachers to progress beyond basic computer literacy. They need a broader range of competencies, including: utilizing technology for personal and professional use, mastering educational approaches that leverage technology, applying technology as a thinking tool, integrating technology as a teaching tool, mastering assessment methods that involve technology, and understanding Information and Communication Technology (ICT) policies in an educational context. Weber and Greiff (2023) emphasize that technology is crucial in fostering seven key 21st-century skills—technical, information, communication, collaboration, critical thinking, creativity, and problem-solving—especially relevant in early childhood education when supported by appropriate developmental foundations.

However, the 2018 Teaching and Learning International Survey (TALIS) conducted by the OECD (2019) highlighted a significant gap in teachers' readiness to integrate technology into their classrooms, with only 43% of educators across participating countries feeling adequately prepared. This widespread need for technology-related training has driven many nations, including the Philippines, to prioritize assessing and developing teachers' technology competence, recognizing it as a crucial component for modern, practical teaching. Teachers' technological competencies must focus on general pedagogical-technological competencies and subject-specific technological competencies (Thoms et al., 2022). This facilitates students' learning and knowledge acquisition, improves and innovates teaching to cater to the diverse needs of the digital era, and contributes to professional development in response to the changes occurring in society and schools (de Catalunya, 2018). Teachers should possess a set of knowledge, skills, strategies, and attitudes, and adhere to pedagogical and didactic principles for integrating digital technology into their instructional practices (Santos & Castro, 2021; Benali et al., 2018).

Several studies have found that TPACK has a significant influence on teachers' and students' academic performance. Teachers with a higher TPACK level are more effective and perform better (Tosuntaş, 2021). De Vera et al. (2021) found that teacher-participants possess strong TPACK, specifically in the content and pedagogical components; however, their technological component and the intricate combination of teaching content using appropriate pedagogy and technology are not as strong. Although science teachers are very competent in teaching Science subjects in the K-12 curriculum, they often lack sufficient knowledge to utilize advanced technology in practical work sessions and their educational practices (Nipales, 2019). Additionally, Agustini et al. (2019) investigated teachers' content knowledge and pedagogy content knowledge variables as having high means compared to other variables; their technological knowledge was the lowest among the variables. Teachers should develop competence in technological knowledge to effectively integrate technology, enhance student learning, stay current with digital trends, and support digital literacy, laying a strong foundation for TPACK. Samson et al. (2021) studied that 80 science teachers from public secondary schools in the Philippines were competent in finding, understanding, utilizing, and creating digital information. However, it is essential to consider that TPACK competence encompasses not only technological skills but also pedagogical and content knowledge. While teachers may be proficient in digital literacy, their ability to integrate technology into science teaching effectively depends on their pedagogical approaches and understanding of scientific concepts.

On the other hand, self-efficacy refers to a person's belief in their capability to succeed in particular situations, overcome challenges, and complete tasks successfully (Williams et al., 2023; Bandura, 1977). This translates to teachers' confidence in using various strategies to achieve desired learning outcomes, even with challenging students (Barni et al., 2019; Christopherson et al., 2016). Similarly, technology self-efficacy refers to confidence in one's ability to use technology effectively (Christensen & Knezek, 2017). Additionally, teachers' technology integration self-efficacy refers to their perception of the capability to effectively master and utilize technologies, such as computers, the internet, and multimedia, to achieve specific teaching objectives (Wang & Zhao, 2021). Teachers' self-efficacy is one of the essential human factors regarding technology integration in the classroom (Clipa et al., 2023). By improving technology integration self-efficacy, teachers can effectively develop their TPACK competence, integrating technology, pedagogy, and content to enhance student learning outcomes in science education.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) encourages educational institutions to utilize technology for instruction through multiple frameworks and guidelines. The UNESCO ICT Competency Framework for Teachers (CFT) recommends a comprehensive system to equip educators with the necessary competencies for effective technology integration and to enhance learning outcomes through technology (UNESCO, 2020; UNESCO, 2018; UNESCO, 2023). By developing their technological skills, teachers can feel more confident using technology, create a sense of mastery over digital tools, and increase their willingness to integrate technology into teaching practices. Additionally, the Department of Education has issued guidelines for implementing the DepEd Computerization Program (DCP). As stipulated in DepEd Order No. 016, s. In 2023, the DCP aims to provide public schools and DepEd offices with appropriate, quality, and equitable technologies that would enhance the teaching, learning, governance, and operation processes, practices, programs, and policies to meet the challenges of the modern age. This supports the Philippines Professional Standards for Teachers (Department of Education Order No. 42, s. 2017), which articulate that teachers need to have a strong understanding of the subject in terms of content and pedagogical knowledge, while demonstrating skills in the positive use of technology to facilitate the teaching and learning process. Government initiatives and professional development programs have been launched to support the adoption of digital technology in education, aiding in the digitalization process (Antonietti et al., 2022). If educational administrators support technological integration, science teachers are likely to develop stronger TPACK competence and enhanced self-efficacy beliefs, leading to more effective technology use and improved student learning outcomes.

Enhancing technology integration self-efficacy beliefs among science teachers is vital for effective technology integration in science education. Research suggests that teachers with high self-efficacy beliefs in technology integration are more likely to use technology consistently and effectively, develop innovative lesson plans, and engage students in meaningful learning experiences. Villasanta (2022) pointed out that integrating technology makes teaching science concepts more effective than the lecture-discussion method. This shows how this approach empowers students to actively discover and construct scientific knowledge through engaging activities and interactive learning experiences. Multimedia tools, for instance, can enhance knowledge assimilation and retention, making learning more enjoyable. Afful et al. (2017) also highlighted the potential of technology to support innovation in teaching and learning. Technology has also paved the way for science teachers to enhance their lessons, making them more interactive and engaging, thereby improving their pedagogies.

Additionally, contemporary technology presents numerous opportunities to enhance classroom instruction and student engagement, potentially impacting students' fine motor development and problem-solving skills (Carstens et al., 2021). Technological revolutions have transformed our societies and how people live, work, and think (Schwab, 2016; Grabe & Grabe, 2007). Schools should integrate technology into their curriculum to prepare students for the demands of the knowledge society (Ghavifekr & Rosdy, 2015), where information is readily available and critical thinking becomes essential. In this context, technology becomes a powerful tool for transforming education, equipping students with the skills necessary to flourish in today's digital age (Blackwell et al., 2014). However, teachers must possess the required competencies (knowledge, skills, literacies, and attitudes) essential to leverage digital technologies for improving the education process and effectively prepare their students for life and work in a digital society (Redecker & Punie, 2017).

Moreover, learners today are often referred to as future-engaged citizens, so teachers need to be technologically savvy to meet the demands and expectations of these modern learners. Transitioning from traditional to student-centered learning experiences necessitates the interplay between how a subject is taught (pedagogy) and the tools used (technology) to convey the subject content (Samson et al., 2021). Teachers can provide meaningful and productive teaching and learning by innovating their pedagogy with appropriate technology (D'Angelo, 2018). For instance, teachers can use technology to implement problem or project-based learning (OECD, 2018), where students collaborate online to discuss real-world issues. Additionally, online simulations and interactive platforms can create engaging environments accommodating diverse learning styles. However, this shift entails prudent decision-making and planning by educators and administrators.

Utilizing modern technologies in science education is crucial for developing 21st-century skills. These skills encompass information literacy, enabling learners to evaluate online resources analytically; media literacy, allowing them to distinguish fact from fiction; and technology literacy, equipping them with digital competencies to effectively utilize digital tools in response to job market demands. Consequently, educational institutions are encouraged to use various technological tools and digital media to improve K-12 education (Hoban et al., 2016; Tikva & Tambouris, 2021). Examining and assessing the teacher's preparedness and acceptance of technology integration in teaching (Hero, 2020).

Studies have emphasized that teachers believe in the potential of technology to enhance student engagement, motivation, and understanding of complex scientific concepts. When integrated effectively, technology can assist teachers in motivating students practice scientific methodologies such as conducting research, designing, and carrying out experiments; analyzing and visualizing abstract scientific concepts; encouraging the replication of real-world problems; and developing students' social and problem-solving skills (Kynigos et al., 2024; Tesalona, 2019). Technology enables active learning, fosters collaboration, and stimulates creativity, increasing motivation and improving critical thinking, problem-solving, and communication skills (Abdullahi, 2014; Engeness, 2020). Additionally, it enables learners to develop necessary skills and expand their knowledge (Chen et al., 2018). It promotes collaborative learning, the development of 21st-century skills, and students' independence for learning (van Laar et al., 2017; Scott & Martin, 2019).

As Kapadia (2024) pointed out, integrating technology is transforming modern classrooms, resulting in a shift from conventional setups to more dynamic, technology-driven learning environments. However, the effectiveness of technology-integrated pedagogical approaches depends on how efficiently educators utilize technology in their educational practices. Effective technology integration requires collaboration between teachers and school systems, ensuring optimal technology use and fostering innovative teaching and learning approaches within the curriculum (Tomaro & Mutiarin, 2018). For this to succeed, teachers require proper training to incorporate technology into the curriculum effectively. Such technology training can positively impact students' learning experience and support them in achieving their academic goals (Hilkemeijer, 2024). This disrupts traditional methods and demands greater creativity to adapt and personalize teaching materials and strategies.

Studies suggested that teachers with higher self-efficacy for using technology are more likely to persevere through difficulties and find solutions, ensuring a smoother technology integration process (Barni et al., 2019; Teo, 2014; Fanni et al., 2013). Furthermore, self-efficacy is positively correlated with various digital competencies, including information literacy, communication, and problem-solving (Wang et al., 2021; Knezek et al., 2002). This highlights the importance of exploring teachers' self-efficacy beliefs for a more comprehensive understanding of technology integration. While teachers had opportunities to develop digital skills and communication methods during the COVID-19 pandemic, self-efficacy beliefs continued to be an issue (Saavedra, 2020). This highlights the importance of supporting teacher development through targeted, advanced technology-based training.

Teachers with a strong belief in technology integration self-efficacy are more likely to achieve a higher level of TPACK (König et al., 2022; Ladendorf et al., 2021; Chen, 2018; Hsu et al., 2017). Research also suggested that while TPACK positively influenced teachers' technology integration self-efficacy, pedagogical knowledge had an adverse effect, and technological content knowledge showed no significant impact (Durak, 2021; Wang, 2020, 2022; Yang, 2018; Joo et al., 2018). Given this, teachers who believe in effectively using technology in the classroom are more likely to develop the skills and knowledge needed to blend technology, pedagogy, and subject content. This connection underscores the importance of building teachers' confidence in using technology, as it plays a crucial role in helping them effectively integrate digital tools to enhance teaching and learning.

Several studies have explored various factors that affect teachers' technology integration self-efficacy beliefs. Sabic et al. (2022) found that males and younger teachers report higher levels of self-efficacy for using technology in teaching than females and older teachers. For less common and more advanced computer skills, such as sending an attachment via e-mail, forwarding an e-mail, and downloading programs or documents from the internet, men showed more self-efficacy than women (Meelissen, 2005). Ifinedo et al. (2020) also found that men's information technology integration self-efficacy is significantly higher than women's. However, research in this area is limited and inconclusive, particularly regarding the combined influence of age and gender (Sarfo et al., 2017; Siddiq & Scherer, 2016). Studies have also shown no difference in teachers' technology integration self-efficacy between genders (Chen, 2021). This study will investigate factors, such as the number of training sessions attended, teaching experiences, and school level, that influence science teachers' TPACK competence and technology integration self-efficacy beliefs in Ifugao.

Technology integration, particularly in science education, has become increasingly essential in the rapidly evolving educational landscape. Recognizing the vital role of educators in facilitating effective technology integration, this study explores teachers' TPACK competence and self-efficacy beliefs concerning the infusion of technology tools in science instruction, particularly in Ifugao's Junior and Senior High Schools. According to UNESCO ICT CFT (2018), technology plays a significant role in achieving the Sustainable Development Goals (SDGs). Thus, this study aligns with the United Nations Sustainable Development Goal 4 (Quality Education) by potentially enhancing teachers' competence in integrating technology into science education. In essence, well-equipped science teachers are crucial for smooth technology integration.

This study is significant because it has the potential to inform teacher professional development programs, enhance science education in Ifugao, improve student learning outcomes, and contribute to the understanding of TPACK competence and self-efficacy beliefs related to technology integration. Thus, this study aims to determine and investigate the teachers' TPACK competence and technology integration self-efficacy belief level in teaching science among junior and senior high schools in Ifugao.

2.0 Methodology

2.1 Research Design

This study employed a descriptive-correlational research design to investigate the relationship between science teachers' TPACK competence and their technology integration self-efficacy beliefs. The descriptive aspect of the design enabled the assessment and description of the levels of TPACK competence and self-efficacy beliefs among science teachers. The correlational component examined the degree of the relationship between the variables. This design was selected because it provides a comprehensive understanding of the current state of TPACK competence and self-efficacy beliefs among science teachers, as well as the nature of their relationship, thereby informing potential interventions and professional development initiatives.

2.2 Research Locale

This study was conducted in all secondary schools of Ifugao, a province located in the Cordillera Administrative Region with a total population of 207,498. It comprises 11 municipalities and houses six private and 35 public secondary schools.

2.3 Research Respondents

The population of this study consists of public Junior and Senior High School science teachers in Ifugao, Philippines. A sample of 100 teachers will be selected using a stratified random sampling technique, which involves a survey questionnaire to gather data on their TPACK competence and technology integration self-efficacy beliefs. This study includes teachers currently teaching science in Junior and Senior High Schools, employed in public schools in Ifugao, and willing to participate in the study. Conversely, this excludes the non-science teachers, teachers from private schools or schools outside Ifugao, and administrators or non-teaching staff, thereby focusing the study on public school science teachers in Ifugao.

2.4 Research Instrument

The instrument used in this study is a 4-point modified Likert scale survey questionnaire. The questionnaire proper was subdivided into two parts. The first part contains the Technological, Pedagogical, and Content Knowledge (TPACK) competence adopted by Schmidt and Thompson (2009). The second part encompasses science teachers' self-efficacy beliefs (STSB) levels regarding technology integration. The statements were based on the National ICT Competency Standards for Teachers.

Moreover, the instrument was used to determine the TPACK competence (STTC) and self-efficacy beliefs (STSB) of science teachers in integrating technology. The items in the questionnaire were graded on a four-point modified Likert scale, with four being the highest (Strongly Agree) and one being the lowest (Strongly Disagree). The mean scores that fell within $1.0 \leq M \leq 1.75$ were considered beginning level, those within $1.76 \leq M \leq 2.50$ were considered developing level, and those that fell within $2.51 \leq M \leq 3.25$ were considered experienced level. In contrast, those with $3.26 \leq M \leq 4.00$ were regarded as having an expert level. Other information about the respondent-teachers, such as sex, age, length of service, type of school, purpose of technology use, and number of training sessions attended, was also provided in the questionnaire.

To ensure the research questionnaire's content and construct validity, the questionnaire was validated both internally and externally by the research adviser and English educators, which led to the removal of vague statements. Regarding the reliability of the questionnaire, the researcher employed a pilot test method to assess the degree of interrelationship among the items on the survey questionnaire. The pilot testing was conducted in Kiangan, where 54 elementary and secondary science teachers were randomly selected to participate in the test. The results of the pilot testing were analyzed using Cronbach's alpha test to measure the instrument's internal consistency. A Cronbach's alpha of 0.70 indicates acceptable internal reliability, 0.80 shows good internal reliability, and 0.90 or greater indicates excellent internal consistency (Emerson, 2019; George & Mallery, 2003). The reliability test results of the teachers' TPACK competence and technology integration self-efficacy beliefs in teaching science were excellent (STTC = 0.955; STSB = 0.954).

2.5 Data Gathering Procedure

This study used specific steps to gather necessary data. Firstly, the researcher obtained permission from the Department of Education (DepEd) – Ifugao Division Office to conduct the study. Approval was also obtained from the selected principals of junior and senior high schools. Secondly, the researcher identified the population of science teachers in junior and senior high schools of Ifugao and selected a sample of teachers using a stratified random sampling. Afterwards, the clarity and conciseness of the survey questionnaire were ensured before distributing it to the selected science teachers. For data gathering, the researcher visited selected public schools in Ifugao to distribute a survey questionnaire to the respondents. Additionally, a Google Forms link was provided to respondents who preferred an online survey, allowing them to respond conveniently. Lastly, the gathered data were analyzed using descriptive and inferential statistics through the Statistical Package for Social Sciences (SPSS) version 20. The study was completed in approximately 4-5 months, spanning from securing the necessary permits and letters to data analysis.

2.6 Data Analysis

Quantitative data collected from the survey questionnaires were analyzed using SPSS software. Descriptive statistics (mean, frequency, and percentage) were used to describe the levels of TPACK competence and technology integration self-efficacy beliefs among science teachers. Inferential statistics (correlation, t-test, and ANOVA with Post-Hoc test) were employed to examine the relationship between TPACK competence and self-efficacy beliefs and compare differences in TPACK competence and self-efficacy beliefs across various demographic groups.

2.7 Ethical Considerations

This study protected respondents' rights and welfare through several ethical considerations. Informed consent was obtained from all respondents, who were informed about the study's purpose and procedures. Respondents' confidentiality and anonymity were ensured through coded identifiers, and all data collected were kept secure and confidential. Additionally, respondents were informed of their right to withdraw from participating in the study without any consequence. The researcher also obtained the necessary permits and approvals from the relevant authorities before data collection. By taking these measures, the study prioritized the well-being and privacy of its respondents.

3.0 Results and Discussion

3.1 Profile of the Respondents

The results show that most of the science teacher-respondents are female (93%) and belong to the age group of 41 and above (46%), with service experience ranging from 6 to 8 years (20%). Most science teachers in Ifugao belong to the junior high school department (74%) and are in public schools (88%). Additionally, 47 (47%) of 100 science teachers attended one or two seminars or training on technology within the years 2020 – 2024.

The most used technology tools for science teaching are a laptop (51%), followed by a smartphone (49%), PowerPoint (47%), printers (45%), and a television or smart TV (41%). The primary purpose of utilizing technology tools is to prepare a lesson plan (54%). Other purposes of technology utilization include, but are not limited to, preparing assessments such as quizzes, examinations, and activities (49%), computing grades (44%), developing instructional materials (42%), and personal or recreational use (41%).

3.2 Level of the Science Teachers' Technological, Content, and Pedagogical Knowledge (TPACK) Competence

Table 1 shows the competence level of Ifugao science teachers in the identified knowledge domains. Generally, science teachers had an *experienced level* of competence in TK, CK, PK, TCK, PCK, and TPK. This suggests that science teachers, on average, possess a skilled level of TPACK competencies, enabling them to effectively incorporate various technology tools and resources into their teaching strategies and practices. Msafiri et al. (2023) emphasized that experienced science teachers demonstrate a high level of proficiency in integrating technology into their pedagogical approaches, contributing to improved educational outcomes.

Table 1. *Competence Level of Science Teachers' TPAC Knowledge*

Knowledge Domains	Mean	Adjectival Rating
Technology Knowledge (TK)	2.85	Experienced Level
Content Knowledge (CK)	2.92	Experienced Level
Pedagogical Knowledge (PK)	3.21	Experienced Level
Technological Content Knowledge (TCK)	2.86	Experienced Level
Pedagogical Content Knowledge (PCK)	2.81	Experienced Level
Technological Pedagogical Knowledge (TPK)	3.07	Experienced Level
Overall TPACK	**2.95**	**Experienced Level**

3.3 Science Teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs Level

The summary of the descriptive statistics for the two variables, along with the mean difference between science teachers' Technological, Pedagogical, and Content Knowledge (TPACK) Competence and Technology Integration Self-Efficacy Beliefs, is presented in Table 2. The table below shows that science teachers' competence towards TPACK is at an experienced level. This means that they consistently demonstrate proficiency in leveraging various technology tools and resources to create pedagogical strategies that enhance subject content delivery, leading to improved student engagement and learning outcomes. According to Ozden et al. (2022), experienced teachers regularly utilize diverse technology tools to enhance students' engagement and effectively meet learning objectives. Anderson (2018) further emphasized that teachers who have experienced TPACK competencies can provide a conducive learning environment by strategically utilizing technologies to engage students effectively.

Table 2. *The Summary of Science Teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs Level*

Variables	Mean	Mean Difference	Adjectival Rating
TPACK Competence	2.95	-0.33	Experienced Level
Technology Integration Self-Efficacy Beliefs	3.28		Expert Level

On the other hand, the self-efficacy beliefs of Junior and Senior High School science teachers towards technology integration are at an expert level. This implies that science teachers display high self-assurance in technology integration, can adapt pedagogical strategies to utilize technology effectively, and promote technology integration within their educational community. This finding corroborates the study by Birişçi & Kul (2019), which states that stronger self-efficacy leads to more effective and sustained technology utilization in education. Moreira-Fontán et al. (2019*)* claimed that educators with higher technology integration self-efficacy beliefs tend to show a more positive attitude towards technology integration.

Comparing the two variables, teachers' technology integration self-efficacy is higher than their TPACK competence (MR = 3.28>2.95). The findings strongly suggest a need to bolster teachers' confidence by developing TPACK competence among science teachers to fully integrate technology with their innovative pedagogical strategies through targeted training and professional development programs. Scherer et al. (2019) noted that while teachers have a high level of self-efficacy regarding technology use, their actual competence in utilizing digital tools may be less developed. This difference between teachers' self-efficacy belief level and TPACK competence also suggests that although the teachers feel prepared for integrating technology in teaching science, they may require more support for proper implementation. In addition, Tondeur et al. (2017) found that even when teachers feel prepared to use technology in their lessons, their actual technological knowledge (TK) and pedagogical content knowledge (PCK) significantly *influence their ability to incorporate technology into their classrooms effectively.* Hence, this implies that teachers need more support in developing their TPACK competence to tie with their technology integration self-efficacy beliefs. Similarly, Voogt et al. (2013) emphasized the importance of complementing practical technological skills with self-efficacy beliefs through ongoing professional development and technology training to bridge the gap between belief and action.

3.4 Correlation between Science Teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs

Correlation analysis was used to determine the relationship between science teachers' TPACK competence and their technology integration self-efficacy beliefs. Table 3 below indicates a strong positive correlation. This means that higher TPACK competence among science teachers is strongly associated with higher self-efficacy beliefs. The *p*-value of 0.000 is less than the conventional alpha level of 0.05, indicating that this correlation, at a 95% confidence interval, is statistically significant and not due to chance. The results further indicate that the null hypothesis, stating there is no significant relationship between teachers' TPACK competence and their self-efficacy beliefs in technology integration for science teaching, is rejected. This strongly suggests a direct association between science teachers' TPACK competence and their self-efficacy beliefs regarding the incorporation of technology tools in science teaching. Thus, this implies that teachers' self-efficacy in using technology tools can positively influence their ability to integrate technology with their pedagogical approaches.

The finding corroborates the studies of Chen (2018) and Ladendorf et al. (2021), which suggest that as teachers' technology integration self-efficacy beliefs become stronger, their TPACK competence level also increases. TPACK was identified as a factor in teachers' technology self-efficacy beliefs (Birisci & Kul, 2019; Kan & Yel, 2019; Cankaya, 2018). The finding further supports the study of Keser et al. (2015), which found that teachers who effectively integrate technology with pedagogical approaches and subject matter tend to feel more confident using digital tools. These findings suggest that teacher training programs should prioritize the development of TPACK and self-efficacy enhancement to support the integration of technology in education in a meaningful and sustainable manner.

Table 3. *The Summary of Pearson Product-Moment Correlation between Science Teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs*

Variables	Technology Integration Self-Efficacy Beliefs		
	Pearson r	P-value	Remarks
TPACK Competence	0.72*	0.000	S

**Correlation is significant at the 0.05 level.* *S – Significant, *NS – Not Significant

3.5 The Difference between Science Teachers' TPACK Competence and Self-Efficacy Beliefs towards Technology Integration when grouped by profile variables

The t-test results for the difference between TPACK competence and technology integration self-efficacy beliefs, grouped by sex category, are shown in Table 4. An Independent Samples t-test was conducted to investigate whether a significant difference in the variances existed. The results show that science teachers' TPACK competence and self-efficacy belief levels did not differ across sex categories. This implies that male and female science teachers have similar competence levels on TPACK domains, demonstrating comparable abilities in integrating technology, pedagogy, and content knowledge. On one hand, the results show no significant difference between TPACK competence and technology integration self-efficacy beliefs across the secondary school level. This implies that science teachers' TPACK competence and technology integration self-efficacy beliefs are similar between junior and senior high schools. This implies that teachers' knowledge and skills in pedagogy, technology, and content are not significantly influenced by the level of secondary education they teach. Overall, the findings suggest that sex category and secondary school level are not determining factors in TPACK competence and technology integration self-efficacy beliefs level among science teachers of junior and senior high schools of Ifugao.

Table 4. *The summary of the t-test between teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs when grouped by profile variables*

Variables	TPACK Competence			Self-Efficacy Beliefs		
	T-test	P-value	Remarks	T-test	P-value	Remarks
Sex	1.15	0.253	NS	0.43	0.668	NS
Secondary school level	-1.16	0.118	NS	-1.10	0.318	NS

*Significance at the 0.05 level. *S – Significant, *NS – Not Significant

The summary of the F-test results for the difference between TPACK competence and technology integration self-efficacy beliefs, grouped by profile variables, is shown in Table 5. An analysis of variance (ANOVA) was conducted to investigate whether a significant difference in the variances existed. The results of the F-test for science teachers' TPACK competence, when grouped according to their profile variables, revealed a substantial effect for age groups and the type of training attended. At the same time, there is no significant effect on the length of service. The p-value indicates that the differences in TPACK competence among age groups, at a 95% confidence interval, are substantial and unlikely to be due to chance. Thus, at least one age group has a significantly different TPACK competence level than the others.

The table below also indicates a statistically significant difference between science teachers' TPACK competence and the number of seminars or training sessions related to technology between 2020 and 2024. This strongly suggests that targeted training programs improve teachers' TPACK competence. Similarly, Sun et al. (2022) also reported that numerous educators achieved an advanced level of TPACK competence through targeted training and resources. Professional development programs aim to guide teachers toward integrating technology effectively into their teaching practices (Ledford, 2016).

Regarding the difference between technology integration self-efficacy and science teachers' profile variables, the results indicate that the training attended significantly affects the science teachers' self-efficacy beliefs in incorporating technology, but has no significant effect on the other profile variables. This implies that professional development programs such as technology-based training positively impact science teachers' self-efficacy beliefs.

School institutions, whether private or public, should prioritize developing teacher training programs on technology to promote effective technology integration into the curriculum.

Table 5. *The summary of ANOVA between teachers' TPACK Competence and Technology Integration Self-Efficacy Beliefs Grouped by Profile Variables*

Variables	TPACK Competence			Self-Efficacy Beliefs		
	F-test	P-value	Remarks	F-test	P-value	Remarks
Age	2.77*	0.032	S	0.99	0.416	NS
Length of Service	0.99	0.450	NS	0.85	0.564	NS
Training Attended	6.07	0.000	S	4.03*	0.005	S

*Significance at the 0.05 level. *S – Significant, *NS – Not Significant

A Scheffé's post-hoc analysis was performed to determine whether the mean score of one group differed from those of the others. The table below shows multiple comparisons of science teachers' competence on TPACK knowledge domains based on their age. Science teachers in the 41 and above age bracket indicate a mean difference of -0.58 compared to the 26-30 age group ($p < .05$). This suggests that younger science teachers have a higher Technological Content Knowledge (TCK) competence level compared to older age groups. The finding contradicts De Vera et al.'s (2021) study, stating that younger teachers often struggle with preparing online instructions due to limited technological competencies. The survey of Kerzic et al. (2021) revealed that age is not a factor determining a teacher's ability to integrate technology into their teaching practices. This implies that teacher training and support programs should focus on skills and strategies rather than assuming age-related differences in technology competence.

Table 6. *Multiple Comparison of Science Teachers' TCK Competence Based on their Age*

Variables	Age Group		Mean Difference	P-value	Remarks
Technological Content Knowledge (TCK)	41 and above	20-25	-0.80	0.059	NS
		26-30	-0.58*	0.017	S
		31-35	-0.44	0.156	NS
		36-40	-0.35	0.249	NS

*Significance at the 0.05 level. *S – Significant, *NS – Not Significant

Table 7 presents multiple comparisons between groups of science teachers based on the number of trainings and seminars they had attended (none, 1-2, 3-4, and 5-6). Teachers who have attended 1-2 training or seminar sessions indicate a mean difference of -0.45 compared to those with no training or seminars ($p = .040 < .05$), demonstrating a higher level of competence in TPACK. Moreover, those who participated in 3-4 trainings or seminars showed a higher mean difference of -0.56 compared to those who had not attended any trainings or workshops regarding technology ($p < .05$), implying greater improvement in Technological Knowledge (TK) competence. The results indicate that science teachers' participation in targeted seminars and training sessions significantly enriches their TK competence levels.

This finding is consistent with several studies that highlight the greater significance of continuous technology-based training for educators. Tondeur et al. (2017) and Voogt et al. (2013) emphasized the importance of ongoing professional development and appropriately designed training programs for teachers to acquire the competencies necessary for effectively integrating technology into their pedagogies and supporting classroom experiences. Essentially, educational institutions should prioritize providing continuous professional development and targeted training, ensuring that teachers are competent in using technology tools for science education, given that educational technology is constantly evolving (Engeness, 2020).

The table below shows that science teachers who attended 1-2 seminars or trainings on technology have a mean difference of -0.55 compared to those with no workshops or trainings, signifying higher levels of competence on Technological Content Knowledge (TCK). This strongly suggests that equipping science teachers with the necessary technological knowledge and skills can enhance their competence in incorporating technology into their pedagogical practices, allowing them to design more interactive, engaging, and effective learning experiences for their students. Additionally, school and educational institutions should prioritize participating in high-quality technological professional development for science teachers.

The results further show that 1-4 training sessions or seminars on technology have a significant impact on the Pedagogical Content Knowledge (PCK) competence level of science teachers compared to those without technology-based workshops or training. Conversely, science teachers who attended more than four sessions did not differ significantly from those who had participated in no seminars or fewer than four seminars or trainings. Teachers may already have gained basic knowledge and skills in technology through one to four training sessions and workshops. In other words, add-on seminars or trainings may be redundant or do not provide more advanced concepts that could further build up their competence. The nature and quality of the training may also play a role, and more specialized workshops or hands-on opportunities could help see further significant gains.

Table 7. *Multiple Comparison of Science Teachers' TK, TCK, and PCK Competence Based on the Number of Trainings or Seminars Attended*

Variables	No. of trainings attended		Mean Difference	P-value	Remarks
Technological Knowledge (TK)	None	1-2	-0.45*	0.040	S
		3-4	-0.56*	0.017	S
		5-6	-0.53	0.254	NS
		9 above	-0.96	0.187	NS
Technological Content Knowledge (TCK)	None	1-2	-0.55*	0.018	S
		3-4	-0.49	0.095	NS
		5-6	-0.58	0.258	NS
		9 above	-1.08	0.168	NS
Pedagogical Content Knowledge (PCK)	None	1-2	-0.60*	0.001	S
		3-4	-0.68*	0.001	S
		5-6	-0.53	0.232	NS
		9 above	-1.01	0.138	NS

*Significance at the 0.05 level. *S – Significant, *NS – Not Significant

Table 8 presents the difference between science teachers' technological integration self-efficacy beliefs and the number of trainings or seminars attended. The Scheffé test reveals significant differences in technology integration self-efficacy beliefs among science teachers with varying levels of technology-based training or seminar experience. Science teachers who have received 1-4 trainings or seminars have significantly higher technology integration self-beliefs than those who have received no training or more than five trainings or workshops. This implies that providing science teachers with technology-based training or seminars, even a limited number of sessions, can enhance their technology integration self-efficacy beliefs. According to Zhang et al. (2021) and Rizzi (2020), professional development has a significantly positive effect on teachers' technology integration, improving their perceptions of readiness and meeting the necessary competencies. Thus, it boosts science teachers' confidence in integrating technology into the delivery of their lessons.

Table 8. *Multiple Comparison of Science Teachers' Technology Integration Self-Efficacy Beliefs Based on the Number of Trainings Attended*

Variables	Age Group		Mean Difference	P-value	Remarks
Technology Integration Self-Efficacy Beliefs	None	1-2	-0.40*	0.022	S
		3-4	-0.44*	0.023	S
		5-6	-0.50	0.142	NS
		9 above	-0.53	0.572	NS

*Significance at the 0.05 level. *S – Significant, *NS – Not Significant

4.0 Conclusion

This study provides significant insights into the TPACK competence and technology integration self-efficacy beliefs of science teachers in junior and senior high schools in Ifugao. The findings showed that science teachers' belief in technology integration self-efficacy is somewhat higher than their TPACK competence. While science teachers possess expert technology integration self-efficacy beliefs, their TPACK competence must be improved through professional development and targeted training. The difference between technology integration self-efficacy beliefs and TPACK competence highlights the need for continuous support to bridge the gap between teachers' confidence levels and practical skills. Moreover, a strong correlation exists between science teachers' TPACK competence and their self-efficacy in technology integration.

Additionally, science teachers from different age groups may vary in their ability to effectively integrate technology, pedagogy, and content knowledge. Younger science teachers tend to demonstrate higher levels of TCK competence than their age counterparts. The number of trainings or seminars attended has affected the TPACK competence and technology integration self-efficacy beliefs. This suggests a need for specific advanced training, mentorship, and reflective practice to support personal and professional growth and enhance self-efficacy beliefs. Schools should also encourage teachers to undertake collaborative lesson planning using TPACK principles. Collaborative models of learning, such as peer coaching or professional learning communities, may provide opportunities for teachers to share best practices more effectively, refine their ability to integrate technology into teaching, and enhance their knowledge about the intersection of technology, pedagogy, and content in the classroom. Future researchers may use a mixed-methods research design to explore the impact of professional development and the influence of school culture and leadership on TPACK and technology integration self-efficacy.

5.0 Contribution of Authors

As the sole author, I take full responsibility for the conceptualization, literature review, data collection, data analysis, writing, editing, methodology, and conclusions drawn in this paper.

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7.0 Conflict of Interest

The author declares no conflict of interest.

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