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Technological, Pedagogical, and Content Knowledge of Secondary Science Teachers in Santa Maria, Ilocos Sur

[1] **Amara Hyacinth Depone Bajet,** [2] **Marites J Yacap**
[1, 2] Master of Science in Education, Ilocos Sur Polytechnic State College, STA. Maria, Ilocos Sur, Graduate School, Philippines

Corresponding Author: **Amara Hyacinth Depone Bajet**

Abstract
This study determined the Technological, Pedagogical, and Content Knowledge (TPACK) of secondary science teachers in the municipality of Santa Maria, Ilocos Sur. Main objectives include testing whether the TPACK of these teachers is consistent with the level of knowledge about the three components: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK); in addition, establishing their relationship to particular demographic characteristics like age, sex, level of education attained, years spent teaching, and science training. Besides that, the study establishes the types of educational technologies utilized by science teachers and their application in daily teaching.
The research made use of descriptive and correlational design. Data were collected using a validated questionnaire administered to 26 science teachers and 374 grade 10 students in the different schools of Santa Maria, Ilocos Sur. The questionnaire was divided into two parts. The first part gathered information about the profile of science teachers and the available technologies used by them with the number of hours of usage per day. The second part assessed the TPACK level of the science teachers.
Findings indicate that TPACK levels differ among science teachers based on their professional profiles. There are big differences in the usage of educational technologies based on the experience and training levels of the teacher. The research also shows that both teachers and students perceive the TPACK of science teachers positively but with a highly significant difference. In addition, there was a strong correlation between the teachers' profile, particularly in their use of software like Microsoft PowerPoint, Google Meet, and hardware like desktop computer/laptop, printer, scanner, flash drives and speakers, and their TPACK level, indicating that these factors play a key role in enhancing their technology integration in science teaching.
In summary, the study identifies a need for professional development aimed at the effective infusion of technology within pedagogy and content in the teaching setting. The overall implication is that boosting teachers' TPACK through extended training and engagement with educational technology would greatly contribute to bettering the effectiveness of their teaching activities and, thus, student performance. Recommendations from this study could be to offer focused workshops or seminars to support the teachers' improvement in the use of technology while teaching science for better student learning.

Keywords: Technological, Pedagogical, Content Knowledge, Science Teachers, TPACK

1. Introduction

Background of the Study

Many aspects of human life have been radically transformed in the twenty-first century, and technology has been instrumental in the development of society. The validity of integrating technology into teaching and learning processes is demonstrated by the fact that technological innovations have transformed various fields, including education. Technology is an integral part of modern education since it enables students to develop critical thinking, problem-solving, and information literacy skills that are very important in today's interconnected and globalized world.
The National Science Teaching Association (NSTA) recognizes that science education is one of the most important disciplines in producing holistic learners who will be competent in satisfying the demands of the future. The NSTA recognizes that science education offers an excellent environment for developing essential 21st-century skills.
Teachers must adopt 21st-century teaching techniques that effectively incorporate technology if they are to maintain and improve the quality of education. Teachers are very instrumental in providing children with the wherewithal to cope

successfully with life in a technologically advanced society. The foundation of high-quality education is excellent instruction, and the wide variety of technology resources at our disposal today provides teachers with the opportunity to adapt their methods and meet the changing demands of their pupils.

Students born between 1980 and 1994, referred to as "digital natives," thrive in learning environments that incorporate technology because it reflects their daily lives (Noguera, 2015; Schweighofer *et al*., 2015) [34, 42]. Moreover, Rone *et al*. (2023) [41] emphasized how children are increasingly relying on media and technology to learn, placing a particular onus on teachers to modify their teaching practices to fit the preferences and learning styles of students. All these point out how crucial technology is to education, especially in making learning interesting and relevant.

In addition, Altun and Akyildiz (2017) [4] highlighted that among the significant responsibilities of the education sector is preparing society for the workplace that is increasingly based on technology. Teachers have to update their practices and adopt frameworks that enable them to integrate technology into their practices seamlessly. One of the appropriate frameworks in this regard is the Technological Pedagogical and Content Knowledge – TPACK paradigm proposed by Mishra and Koehler (2006) [29]. The framework provides instructors with a place to begin unraveling the complexities of modern education by focusing on how technology, pedagogy, and content interact in effective teaching.

TPACK has mainly been examined among pre-service and in-service instructors in the fields of educational technology. Studies have focused for the most part on the TPACK abilities-teacher profiles relationships at various points, often letting go of what specific technologies give rise to practices in teaching and learning. For this reason, a knowledge void exists on whether and how accessible technologies influence teachers in their TPACK competencies and so in their capability as instructors. Filling in this gap can help create strategic plans to implement technology-supported enhancement of education quality.

The rich context provided by scientific education makes the work of science instructors especially important for the use of technology in the classroom. Teachers can use technology to create an engaging and productive learning environment for students in scientific lessons. However, it is necessary to evaluate how science instructors use the technologies available to them and how this integration fits into their TPACK competencies.

Through the assessment of science teachers' TPACK abilities and an investigation into the relationship between their use of technology and their teaching methods, this study attempts to close this research gap. Specifically, the research seeks to establish whether the incorporation of technology into instruction enhances its effectiveness and translates into improved student outcomes. In addressing these objectives, the study provides insightful information on how to improve scientific education using technology-assisted teaching, which ultimately serves the broader objective of achieving high-quality education in the twenty-first century.

Framework of the Study

The following concepts and theories provide a clearer perspective of this study.

This study is grounded on the TPACK framework (Mishra & Koehler, 2006) [29]. It is a very useful model used by academic stakeholders for understanding and measuring how technology is integrated into the teaching and learning process (Mishra, 2019; Herring *et al*., 2016) [30, 17]. Many educators and leaders have proposed various ways to measure TPACK domains through self-diagnostic questionnaires, interviews and focused discussions, observations, and/or documentary evidence.

Technological knowledge (TK) is an educator's knowledge of how to use and understand technology tools and systems (Adams, 2019) [1]. This includes understanding educational technologies- software, hardware, and digital platforms- and potential applications in the classroom. Pedagogical knowledge (PK) is the strategy and methodology in which teachers would facilitate learning with an understanding of how students learn and how a conducive learning environment can be built. CK relates to a teacher's expertise over content, that is, a mastery over scientific concepts, among others, and how best to convey it to the learners. Combining the domains, however, can facilitate the creation of special areas, including technological pedagogical knowledge (TPK), where pedagogy blends with the technology of teaching strategies, and technological content knowledge (TCK), which unifies the technological dimension with subject content for teaching delivery.

Recent education technology advancements and, most importantly, artificial intelligence tools' integration have expanded the typical TPACK. Celik (2023) [10] proposes the Intelligent-TPACK model, highlighting an ethical aspect of AI-based integration in education. In summary, teachers will need both TK for handling AI tools, as well as PK, as they understand what the AI is contributing to instruction. This integration guarantees that AI tools are used effectively and ethically in the learning environment. In addition, the research emphasizes the importance of teachers' critical evaluation of AI decisions, as it points out the interdependence of TPACK components for meaningful technology integration.

In the contemporary classroom, the TPACK model acts as a guide to overcome challenges such as the lack of access to technology, school culture limitations, and teachers' preconceived notions about the use of technology (Adams, 2019) [1]. Given that science instruction has become dynamic, and educational technology is increasingly becoming available, science educators in the municipality of Santa Maria, Ilocos Sur, will benefit from the use of the TPACK framework, which guides the teacher in utilizing these tools to deliver engaging, student-centered learning experiences that both are technologically facilitated and pedagogically sound.

This study ascertains science teachers' level of TPACK through an appraisal of the subjects' TK, PK, and CK, both teacher and student evaluations. In its effort to look deeper into potential contributors to differences in TPACK, this study considered demographic factors among teachers: their age, gender, educational levels, teaching experiences, and in-service professional training exposures. This research

seeks to contribute to the body of knowledge regarding technology-supported instruction, as well as inform professional development programs designed specifically for science educators in the region, by gaining insight into how these factors interact.
The figure below shows the seven domains of the TPACK model.

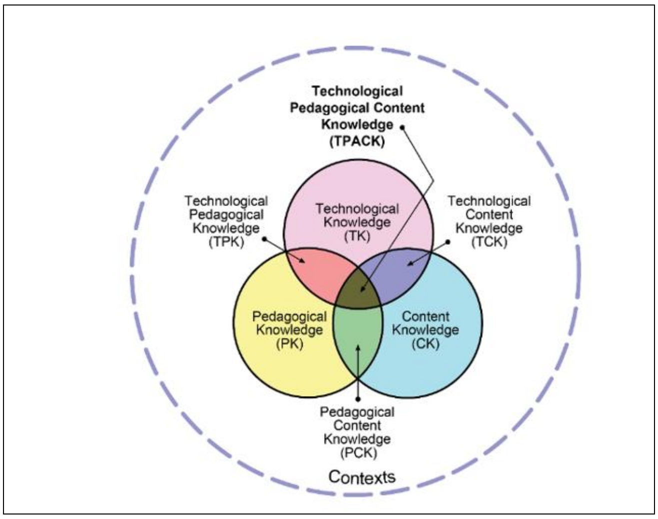

Fig 1: Dimensions of the TPACK Model

The seven domains of the TPACK framework, as shown in Fig 1, include the following (Mishra & Koehler, 2006) [29]:

a. Technological Knowledge (TK), which is the knowledge needed to adapt to the fast development of technology;
b. Pedagogical Knowledge (PK), which is the knowledge of teaching and learning practices, including classroom management, assessment, and the knowledge of how students construct knowledge;
c. Content Knowledge (CK), which is the knowledge about the subject matter;
d. Pedagogical Content Knowledge (PCK), which is the knowledge needed to transform the subject matter and be able to organize conditions to make learning of certain contents easy;
e. Technological Content Knowledge (TCK), which is the knowledge of how technology and content influence one another that leads one to identify what technology can be used for a particular subject;
f. Technological Pedagogical Knowledge (TPK), which is the knowledge needed to identify what technology is appropriate to support a particular pedagogical approach.
g. Technological Pedagogical and Content Knowledge (TPACK), which is the knowledge of utilizing various technologies and pedagogical approaches in teaching different content.

The TPACK framework offers a holistic lens through which this study examines the integration of technology into the teaching practices of science teachers. The interplay between the seven TPACK domains is assessed to determine the extent to which technological, pedagogical, and content knowledge come together to influence teaching effectiveness and student learning outcomes. Its applicability ensures that the research is aligned with a strong theoretical framework while addressing the gaps in literature regarding the relationship between TPACK competencies and the use of specific technologies.

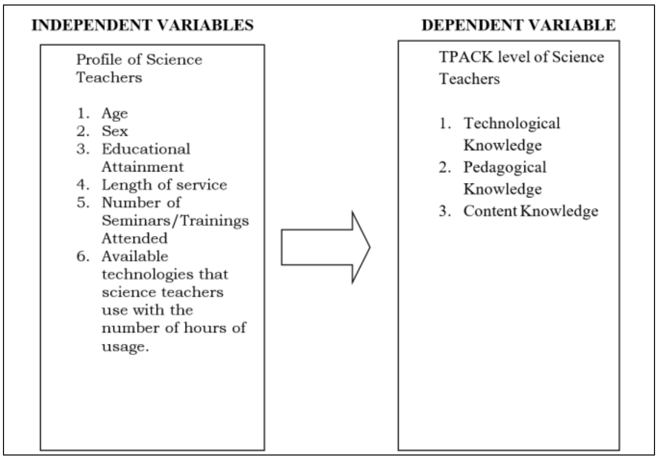

Fig 2: The Research Paradigm

Fig 2 shows the research paradigm of this study. This simplifies the study by illustrating how the study will be conducted using the Independent Variable-Dependent Variable model. A validated questionnaire was administered to the respondents to measure their TPACK and to investigate if there is a significant difference between the perceptions of teachers and students on the TPACK level of science teachers, specifically on the three domains, namely, Technological Knowledge, Pedagogical Knowledge, and Content Knowledge. In addition, this study aims to test if there is a significant relationship between the profile and the TPACK level of science teachers.

Statement of the Problem

This study aimed to assess the TPACK level of science teachers in secondary schools in Santa Maria, Ilocos Sur.
Specifically, the study tried to answer the following questions:

1. What is the profile of the science teachers in terms of the following:
   a. age;
   b. sex;
   c. educational attainment;
   d. number of years in teaching science; and
   e. number of seminars and trainings attended in Science?
   f. available educational technologies that science teachers use in their teaching and how frequently are they using these technologies on a daily basis?
2. What is the level of TPACK of science teachers as perceived by the two groups of respondents along the following components?
   a. Technological Knowledge (TK)
   b. Pedagogical Knowledge (PK)
   c. Content Knowledge (CK)
3. Is there a significant difference between the perceptions of teachers and students on the TPACK level of science teachers?
4. Is there a significant relationship between the profile of science teachers and their TPACK level?

Hypotheses

This study was guided by the following hypotheses.

1. There is a significant difference between the perceptions of teachers and students on the TPACK level of science teachers.
2. There is a significant relationship between the profile of the respondents and the TPACK level of science teachers.

Scope and Delimitation

This study focuses on the assessment of the TPACK level of science teachers and how it affects teaching practices. Specifically, this study explores the relationship between teachers' TPACK competencies and the integration of technology-supported instructional strategies in science education. Additionally, the association between teachers' TPACK levels and science teachers' profiles was determined.

There were 26 science teachers and 374 Grade 10 students involved in this research study. Secondary schools in the municipality of Santa Maria, Ilocos Sur, made up the settings for this research. A validated questionnaire was distributed for the collection of data. Only respondents and one academic year under which the data were collected limited the scope of this study.

Importance of the Study

The results of this study will be beneficial to the following:

Science Teachers. The results of this study will serve as motivation for science teachers to make innovations in their teaching strategies.

Administrators/Head of School. The results of this study will provide insights for the school heads and administrators in motivating teachers to develop their TPACK in teaching towards quality education.

Curriculum Planners. The result of this study will provide an insight into providing better programs/activities suited to the needs of the 21st century learners.

Future Researchers. The results of this study will serve as a basis for further studies about TPACK.

Students. The study will help improve the students' academic performance in Science.

Definition of Terms

The following terms used in the study are operationally defined as follows:

Profile of Respondents

Age – Refers to the actual age of science teachers, expressed in completed years from birth.

Sex – Refers to the respondents' biological categorization as either male or female.

Years of Teaching Experience – Refers to the number of years that respondents have been teaching science subjects.

Position – Refers to the present designation of respondents' job, like teacher I, II, III or master teacher.

Number of Trainings and Seminars Attended – Refers to the total number of relevant science-related professional development activities that the respondents have attended.

Educational Attainment – Refers to the highest academic degree or level of education achieved by the respondents.

Technological Knowledge Domains

Technological Knowledge (TK) – Refers to the knowledge and application of tools, low-tech and high-tech, that include software programs, digital devices, and other online platforms to teach science.

Pedagogical Knowledge (PK) – Refers to the teachers' knowledge of how to teach effectively, which encompasses instructional methods, classroom management techniques, and assessment strategies.

Content Knowledge (CK) – Refers to the mastery of subject-specific knowledge, particularly in science, that a teacher needs to have to teach effectively and learn.

Interrelated Knowledge Constructs

Pedagogical Content Knowledge (PCK) – Refers to the process of making science concepts accessible and understandable by linking the pedagogy used by the teacher with specific content knowledge.

Technological Content Knowledge (TCK) – Refers to knowing how technology can be used effectively to represent and enhance subject-specific content, for example, the visualization of scientific phenomena.

Technological Pedagogical Knowledge (TPK) – Refers to the knowledge the teacher should utilize in incorporating suitable technologies to back up different pedagogies in teaching science.

Technological Pedagogical and Content Knowledge (TPACK) – Refers to the all-inclusive framework that will integrate technology, pedagogy, and content knowledge to give effective and innovative science instruction.

Review of Literature

The following literature and studies were considered relevant to this study.

Profile of Science Teachers

A study recently published by Lai and Jin (2021) [23] investigated the relationship between the demographic characteristics of teachers and their confidence and willingness to integrate technology into teaching activities. It was found that young teachers were very confident and receptive to technology, while older and experienced teaching staff avoided most of the new pedagogical practices and preferred the traditional ones. The difference in generations has made this argument: these differences require a targeted professional development program concerning the needs of novice teachers as well as veteran teachers. This means that educational institutes must design open and adaptive training programs by bridging the technological divide between teachers and providing a fairer chance for incorporating technology.

Nikolopoulou and Gialamas (2015) [33] studied the relationship between years of teaching experience and confidence in integrating technology into classrooms. The study showed that teachers with fewer years of teaching experience generally had more years of computer experience and were more confident in using technology. The findings underscore the need for in-service teacher training programs to include modules on digital literacy and confidence building. Based on these results, it appears that the best thing teacher education policy should focus on is hands-on technology training with supporting systems.

Salvan and Hambre (2020) [9] studied the demographic profile of K -12 teachers in the Philippines and its relationship with the academic performance of learners using Earth and Space modules. Results showed that most teachers were female, relatively young, and pursuing further education but lacked extensive teaching experience in the subject. Results revealed no significant relationship between the teachers' profiles and the performance of the learners, even though some schools reported improved performances of the learners.

Availability and Use of Educational Technologies

Francom (2019) [14] conducted a review on barriers to technology integration in schools and found some of the key challenges to include limited access to resources, inadequate training, and lack of institutional support. It is indicated that the elimination of these barriers would require the strategic investment of infrastructure, teacher training, and policy support in such settings. These findings point to the fact that the achievement of technology-enriched learning environments establishes a condition for improved outcomes in both teaching and learning.

The OECD's (2021) [35] TALIS survey has identified the integration of ICTs as an important area for teacher professional development globally. It, therefore, revealed the importance of equipping teachers with appropriate skills to exploit the use of technology. It further suggests that national education systems need to focus on training and developing the infrastructure of ICTs to make teaching more effective and improve students' learning experience.

The Jiménez Sierra *et al*. (2023) [20] systematic review focused on TPACK development among teachers through Lesson Study. A lesson study gives teachers a reflection and contextualization framework for teacher competencies for information and communication technologies integration in instruction.

Technological Pedagogical and Content Knowledge (TPACK)

The development of Pedagogical Content Knowledge, as postulated by Shulman (1986), considered the integration of pedagogy and content knowledge. Based on this, Mishra and Koehler (2006) [29] established the TPACK model, integrating technology into this concept. Ever since, this has been considered the foundation on which the process of how a teacher can adequately mix content, pedagogy, and technology to foster a meaningful learning process could be derived.

Mishra and Koehler (2022) revisited the TPACK framework to address contemporary challenges, such as remote learning and emerging educational technologies. They emphasized the dynamic nature of the framework, indicating that it can be applied to various teaching contexts. Their findings highlight the relevance of TPACK in preparing teachers to meet the demands of 21st-century education, especially in hybrid and online learning environments.

Koehler and Mishra (2019) [29] considered the flexibility of the TPACK framework, noting the need for teachers to align technology with pedagogy and content. The authors insisted that flexibility and continuous learning are a must to be effective in integrating technology into education. This knowledge underscores the importance of creating adaptive expertise in teachers, thus making them capable of responding to new educational challenges.

Beri and Sharma (2021) [5] designed a valid TPACK scale to measure teacher educators' skill levels in technology integration into pedagogy. Their study identified six dimensions of TPACK, emphasizing pedagogical and creative thinking skills. This scale provides a valuable tool for evaluating the TPACK levels of teachers in the study and points to targeted interventions toward enhancing such skills among science educators.

Lehiste (2020) investigated in-service teachers' participation in professional development programs and found significant improvements in their TPACK competencies. The study found strong correlations between domains like TPK and PCK. Such findings highlight the importance of targeted professional development initiatives that enhance teachers' ability to integrate technology into their instructional practices.

Perceptions of TPACK Levels

Mai and Hamzah (2016) [26] explored the primary science teachers' perceptions of TPACK confidence. The study indicated that there was no significant difference in overall TPACK perceptions by demographic factors, such as age or gender. However, it was found that differences exist in specific domains like PK, TPK, and PCK. These differences vary with the qualifications of the teachers. Such findings indicate the necessity for differentiated professional development approaches to be designed to fill specific gaps in teachers' TPACK competencies.

Valtonen *et al*. (2020) [45] analyzed pre-service teachers' confidence in TPACK skills and identified Pedagogical Knowledge (PK) as a critical area for ICT readiness. The authors stressed that basic pedagogical skills need to be strengthened for the proper infusion of technology in teaching practices. This insight indicates the need for early and integrated teacher education programs that build up a strong base in pedagogy while providing technology integration strategies.

Hunutlu and Küçük (2022) [18] explored the association between perceptions of TPACK of English teachers, use of Web 2.0 tools, workload, and technostress. The results revealed that teachers with lower technostress and higher usage of Web 2.0 tools had better perceptions of TPACK, though increased tool usage also elevated workload. This study suggests that managing technostress and workload is crucial for fostering effective technological integration, offering insights into supporting science teachers in this study.

Irwanto *et al*. (2022) [19] examined Indonesian pre-service teachers' perceptions of TPACK and found that there were strong correlations between dimensions of TPACK and the need for teacher education programs to focus on integrated pedagogy, content, and technology training. These findings underpin the structured development of TPACK initiatives, which can inform both pre-service and in-service training strategies in this research.

Chatmaneerungcharoen (2019) [12] explored the effect of CO-TPACK professional development activities on teachers' TPACK. It shows that the TPACK-related competencies of the teachers improved when they participated in collaborative approaches such as peer learning and group work. Such an outcome underlines the necessity for collaboration and community building in developing teachers to create collective learning and development in TPACK competencies.

Relationships Between Teacher Profile and TPACK Levels

Gonzales (2018) [16] ascertained there is no notable correlation between levels of self-efficacy and TPACK profiles among Senior High School Biology teachers. In relation, Palmares and Batisla-Ong (2023) [39] determined there was no age or years in teaching in which the TPACK varied. The review suggests that maybe the TPACK expertise will not be limited to demographic profiles but rather by a concerted and purposefully planned intervention towards building the competencies.

Scott (2021) [43] reviewed widely used TPACK survey instruments and reported that these were limited in capturing the complexity of the TPACK framework. Özgür (2020) [38] analyzed the relationship between TPACK, technostress, school support, and teacher demographics. The study shows that both school support and high levels of TPACK help alleviate technostress, pointing towards the necessity for support systems within institutions.

A meta-analysis by Zeng *et al*. (2022) [46] found a strong positive correlation between information technology integration self-efficacy and TPACK levels among teachers. The moderator of this correlation was career stage. This study underlines the importance of self-efficacy among teachers as a precursor for enhancing TPACK, which lays a foundation for interventions in my study.

Akturk and Ozturk (2019) [3] discuss the predictive relation between teachers' TPACK, students' self-efficacy, and students' academic achievements. The outcome of the findings is that teacher TPACK as well as students' self-efficacy were strong predictors for academic success. This study supports my research straight away by establishing the impact that teacher competency has on the achievement of students within a technology-oriented educational environment.

Educational Implications of TPACK

Joshi (2023) [21] undertook a systematic review of 75 peer-reviewed articles to synthesize the relationship between TPACK and teachers' self-efficacy. It found the research methodologies, subject domains, and evaluation approaches of studies exhibited trends; therefore, it inferred that professional development interventions played a vital role in augmenting the self-efficacy of teachers about TPACK. Furthermore, it depicted that the practices of TPACK-based argumentation were found helpful for the teachers in gaining a positive attitude towards technology integration into teaching. This review emphasizes the need for teacher preparation programs and professional development initiatives to include TPACK-focused training, which would enable educators to adopt technology effectively in their instructional strategies. The study provides the current research with essential insights as it underlines the importance of professional development in equipping teachers with the necessary competencies to integrate technology, pedagogy, and content knowledge in classrooms.

Filina *et al*. (2024) [13] used a qualitative case study to examine TPACK integration into learning in elementary schools at SD Negeri 16 Banda Aceh. The results revealed that TPACK integration highly boosts teaching skills, as educators will be able to use ICT tools effectively during the planning and execution of lessons. However, other challenges that may arise include minimal access to ICT, poor training, and difficulty in incorporating TPACK into the elementary school curriculum. The findings bring out the importance of tackling the barriers to maximize the benefits of TPACK in fostering engaging and meaningful learning experiences. This piece relates to the current research since it underlines the practical applications and limitations of TPACK, giving a basis upon which strategies can be developed to tackle challenges in the integration of technology at the foundational level of education.

Incorporating TPACK in teacher education has been a landmark step toward handling the challenges that come with 21st-century learning. Recent studies emphasized the need to have continuous professional development programs to enhance teachers' technological literacy and pedagogical skills. Ghavifekr *et al*. (2021) [15] pointed out that aligning technology integration with pedagogical goals and problem-solving strategies ensures meaningful and effective learning experiences. These findings underpin the need for structured professional development programs that are structured and enable teachers to utilize technology in ways that will enhance student learning outcomes.

Research Gap

While the existing literature has emphasized the critical role of teacher demographics, educational technologies, and the TPACK framework in advancing teaching practices, significant research gaps remain concerning the contextual and practical integration of these factors, especially in science education. For instance, Lai and Jin (2021) [23] and Nikolopoulou and Gialamas (2015) [33] emphasize the generational and experiential divides among teachers, which necessitates the development of professional development programs tailored to their needs. The findings, however, are not always specific to science educators.

In relation to the availability and utilization of education technologies, studies by Francom (2019) [14] and the OECD (2021) [35], among others, often have systemic barriers and broad policy implications. However, there is limited exploration of how these challenges manifest at the classroom level. The findings by Salvan and Hambre (2020) [9] highlight the demographic profile of teachers in the Philippines but fail to establish a direct correlation between these profiles and the effectiveness of technology-supported instruction, leaving room for further investigation.

The TPACK framework, established by Mishra and Koehler (2006) [29] and revisited by Mishra and Koehler (2022), gives a holistic model of the integration of technology, pedagogy, and content knowledge. However, studies such as those conducted by Lehiste (2020) and Beri and Sharma (2021) [5] focus more on general or pre-service teacher populations, with not enough attention paid to in-service science teachers. Furthermore, studies, such as by Mai and Hamzah in 2016 [26] and Valtonen *et al*. in 2020 [45], that examine the perception of TPACK levels do not provide a more comprehensive understanding of how these perceptions translate into practices in the classroom or affect outcomes for students.

Although there is research by Gonzales (2018) [16] and Özgür (2020) [38] that assesses the relationship between teacher profiles and TPACK levels, a gap exists in understanding how such relationships influence student engagement and achievement in specific disciplines such as biology. Zeng *et al*. 2022 [46] meta-analysis points out self-efficacy as a very important factor but does not go any further to provide actionable insights for targeted interventions in science education.

This study tries to fill this gap by investigating the relationship between teacher demographics and TPACK competencies in the context of incorporating educational technologies into teaching.

2. Methodology

This chapter presents the research design, population, data gathering instrument and procedure, statistical treatment of data, and data categorization used in the study.

Research Design

This study made use of a descriptive-correlation research design to determine the TPACK level of secondary science teachers of Santa Maria, Ilocos Sur. Descriptive research design is a scientific method that involves describing individuals, events, or conditions by studying them as they are and not trying to manipulate any of the variables (Siedlecki, 2020) [44]. Thus, the profile of the teacher-respondents in terms of age, sex, educational attainment, years of teaching experience, number of seminars attended, and their TPACK level were described in this study. Correlational design is used to determine the significant associations between the profile and TPACK level of the science teachers.

Population of the Study

The respondents of this study were the science teachers and the students at the different Secondary Schools in Santa Maria, Ilocos Sur. These include Santa Maria National High School, Saint Mary's College, Ilocos Sur Polytechnic State College - Laboratory High School, and Ag-agrao National High School.

Table 1: Distribution of Respondents of the Study

School	Number of Science Teachers (f)	Number of Grade 10 Students (f)
Ag-agrao National High School	2	37
Ilocos Sur Polytechnic State College	6	20
St. Mary's College	2	52
Santa Maria National High School	16	265
Total	26	374

Stratified sampling was used to determine the number of student respondents in each participating school. Of the 374 student respondents, 37 were from Ag-agrao National High School, 20 from Ilocos Sur Polytechnic State College, 52 from St. Mary's College, and 265 from Santa Maria National High School.

Research Instrument and Procedure

This study used a questionnaire as the primary instrument in gathering data to assess the TPACK of secondary science teachers in Santa Maria, Ilocos Sur. The instrument was carefully designed to capture both the demographic profiles of the teachers and their proficiency across the three domains of TPACK: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). The questionnaire was divided into two main parts: The first part collected profile information about teacher-respondents, including the variables age, sex, educational attainment, years of experience in teaching, the number of relevant seminars or training programs attended, and available technology usage. These were considered variables that would help better understand the backgrounds of the teachers and possibly establish a connection that may influence their TPACK level. This was done by asking them to assess how proficient they are in using technology with pedagogy and content knowledge. In this section, a Likert scale was applied to the self-rated competence of teachers in these three areas, thereby providing the necessary data for this study.

This instrument was then validated to determine its relevance and appropriateness. It was first screened by the head teacher and principal to ensure that the content aligned with the objectives of the study and was relevant to the local context. After this, a pilot test was conducted among a sample group of teachers whose characteristics were representative of the main respondents. The pilot test aimed to test the clarity and reliability of the instrument. The results revealed that the questionnaire was clear and reliable, thus, it was piloted and finalized after receiving responses from the pilot group.

Table 2: Reliability of Questionnaire

Indicators	Cronbach Alpha	Remarks
Technological Knowledge	0.887	Good
Pedagogical Knowledge	0.885	Good
Content Knowledge	0.864	Good

George and Mallery (2003) provide the following rules of thumb: "_ > .9 – Excellent, _ > .8_ Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable"

Table 2 shows the reliability of the questionnaire. It conveys that the items in the questionnaire are reliable. Cronbach's alpha was used as a statistical procedure to test internal consistency for establishing reliability. This analysis revealed high reliability for each section of the questionnaire, with Cronbach's alpha values of 0.887 for Technological Knowledge, 0.885 for Pedagogical Knowledge, and 0.864 for Content Knowledge. As indicated by George and Mallery (2003), these values fall within the "Good" range, thus, the instrument was consistent and reliable in measuring the intended constructs.

For the data gathering process, the researcher submitted a formal letter of request to the Schools Division Superintendent's office requesting permission to gather data from the secondary schools in Santa Maria, Ilocos Sur. After obtaining such permission, the researcher sought the permission of each school's principal to conduct the study. Once the necessary permissions were obtained, the researcher administered the questionnaires personally to the teacher-respondents. The researcher also guided them to complete the questionnaires without making any mistakes or errors, ensuring that the data collected was correct. Therefore, the overall process of instrument development, validation, and data collection ensured the use of a reliable and valid tool for the study to ensure that the TPACK levels of secondary science teachers are measured correctly.

Statistical Treatment of Data

The following statistical tools were used in analyzing the data gathered in the study:

Frequency Count and Percentage. These are the statistical tools used to collect data on the profile of science teachers.

Weighted Mean. This is the statistical tool used to describe the data on the usage of available technologies utilized by the science teachers and the TPACK level of science teachers, specifically on the three components, namely Technological Knowledge, Pedagogical Knowledge, and Content Knowledge.

T-test. This statistical tool was used to determine if there is a significant difference between the perceptions of the two groups of respondents on the TPACK level of science teachers.

Spearman and Pearson Correlation. This tool was used to determine the significant relationship between the profile of science teachers and their TPACK level.

Data Categorization

The following range and descriptive ratings were used to interpret the data that were gathered in this study.

A. TPACK Components

Rating	Range	Items Descriptive Rating	Overall Descriptive Rating
5	4.21- 5.00	Strongly Agree	Very High
4	3.41- 4.20	Agree	High
3	2.61- 3.40	Neither Agree/Disagree	Moderate
2	1.81- 2.60	Disagree	Low
1	1.00- 1.80	Strongly Disagree	Very Low

3. Results and Discussion

This chapter includes the presentation, interpretation and analysis of significant findings of the current study. This also contains the conclusions and recommendations of the study.

Findings

Profile of the Respondents

Fig 3 shows the distribution of respondents in terms of age.

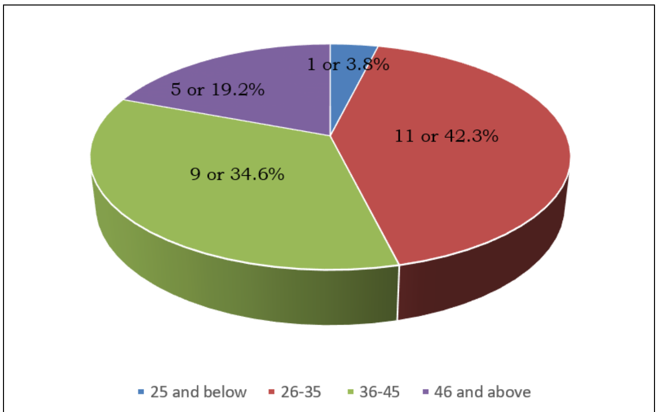

Fig 3: Distribution of Respondents by Age

Fig 3 illustrates the distribution of the respondents by age. The figure shows that 42% of teachers fall within the 26-35 age range, indicating that a significant portion of the teaching workforce consists of young to early mid-career professionals. This finding suggests that many educators are still in the early or developmental stages of their teaching careers, likely gaining experience, refining their teaching methods, and adapting to the evolving educational landscape. Additionally, 35% of the sample falls in the 36-45 age bracket, which can be considered the more experienced of the groups who would probably be well-established within the teaching method as well as knowledgeable in depth. This would align with the general career progression within education, as teachers develop their skills more and more as they go.

In addition, 19% of the respondents fall within the 46 and above age category. This may be a small percentage, but it does constitute a cohort of teachers with years of experience and, thus, must hold a wealth of knowledge and experience. This age group is important as it may give a broader perspective on how the integration of technology in teaching has evolved over the years, given the technological shifts in education. In contrast, only 4% of the respondents are 25 years old or younger, suggesting a relatively lower representation of early-career teachers in this study. This may suggest that the trend among younger teachers may be likely to seek a change in careers altogether or may simply not have settled into their teaching careers yet at the secondary school level.

The age distribution of respondents in this study reflects a diverse teaching workforce with different levels of experience and perspectives, which are congruent with findings in the literature. Teachers aged 26–35, who make up the greatest portion of the sample at 42%, will likely be in the early to middle stages of their careers and may represent some of the most energetic and open teachers to introduce new practices, including technology-supported instruction (Nikolopoulou & Gialamas, 2015) [33]. The most significant proportion of teachers who are 36–45 years old (35%) is consistent with the study by Salvan and Hambre (2020) [9], which hypothesizes that this age group, with some experience, will have the expertise and confidence to combine traditional and modern teaching techniques. Meanwhile, 19% are aged 46 and above and bring along with them a wealth of experience, a critical factor for contextualizing how technology use has evolved in teaching over the years (Lai & Jin, 2021) [23]. The lower percentage of teachers aged 25 and below, at 4%, might suggest the difficulty in keeping young teachers or even the possible desire among these for other careers altogether, which Gonzales (2018) [16] also found during his research on demographic factors affecting teaching styles. Diversity based on age can thus be an imperative characteristic for science education that needs targeted professional development programs that would create effectiveness to address the different needs of the novice teacher and the more seasoned teacher.

Fig 4 shows the distribution of teacher respondents by sex.

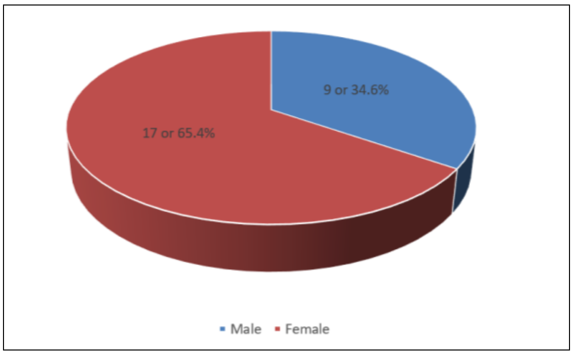

Fig 4: Distribution of Respondents by Sex

Fig 4 illustrates the sex distribution of the teacher respondents, where 65% or 17 teachers are female, and 35% or 9 teachers are male. There is an evident gender imbalance in which females have outnumbered males by 30%. This result has reflected a very documented phenomenon in teaching, not only worldwide but also in the Philippines. As the data from the World Bank revealed, 71.29% of secondary teachers in the Philippines were female in 2021. This fact indicated a substantial gap between males and females in this profession. Such a statistic resonates well with the results of this research: women tend to dominate the teaching profession, a very consistent and ubiquitous phenomenon.

Several factors explain the higher representation of female teachers in this study and the general educational context. In many societies, teaching has generally been viewed as a more female-friendly profession because of its core nurturing and caregiving functions. Moreover, the provision of education is considered by many women to be less of a concrete career and rather an employment that can be considered flexible and, at the same time, matches the respective societal expectations of female roles. It might also indicate that female dominance in the teaching profession mirrors more profound social and cultural aspects, including gender norms and the availability of alternative careers for women outside of education.

Results indicating a higher proportion of female teacher respondents are in line with established literature on gender distribution in the teaching profession. Salvan and Hambre (2020) [9] assert that the dominance of female educators is a trend that has been well-documented in the Philippine education system, echoing global trends. This dominance is explained by the fit of teaching roles into societal expectations and norms around caregiving and nurturing, a domain often perceived as feminine in nature (OECD, 2021) [35]. In addition, studies like Salvan and Hambre (2020) [9] reveal that such gender gaps do not even influence the quality of learning produced, thus, more emphasis should be given to professional development rather than gender representation. The data also informs the idea that female representation in teaching is socially and culturally framed, as mentioned in Francom's (2019) [14] explanation of institutional forces in education. Gendered strategies in addressing secondary education will involve a more strategic approach to equality without making the profession unwelcoming for either gender.

Fig 5 shows the distribution of respondents in terms of educational attainment.

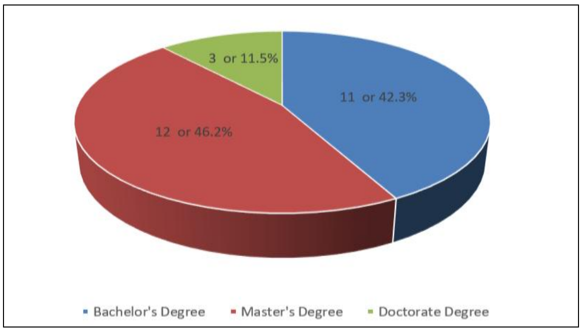

Fig 5: Distribution of Respondents by Educational Attainment

Fig 5 shows the distribution of educational attainment of the respondents, which would show a rather diverse academic landscape. A surprising 46% of the respondents have a master's degree. This means that a large part of the teacher population has pursued higher education beyond the bachelor's level. This is an encouraging reflection of the teachers' commitment to professional development and their drive to enhance their expertise in their field. The presence of a large percentage of master's degree holders conforms to the increase in emphasis on higher qualifications in the teaching profession, as most teachers are encouraged or practically required to pursue higher education and training to enhance their pedagogic practices and increase career prospects.

Meanwhile, 42% of the respondents hold a bachelor's degree, which makes up a big proportion of the sample. The figure indicates that a significant percentage of teachers have completed their bachelor's degree but have not followed up with additional academic qualifications. Although holding a bachelor's degree is still an essential qualification to teach, a high proportion of bachelor's degree holders in this study reflects a basic level of qualification required in the profession.

The figure also reveals that only 12% of the teacher-respondents hold a doctorate, indicating that a relatively small portion of teachers have pursued the highest level of academic attainment. This smaller portion is often linked with leadership positions, advanced research, or niche areas within the education sector. The fact that the sample contains a few doctorate holders supports the notion that at least some of the teachers included in the study are highly specialized and have likely made contributions to the academic community through research or other scholarly activities.

As illustrated in Fig 5, this wide range of years of education among the respondents is a hallmark trend in teacher professional development. This finding revealed that 46% of the teachers participating in this study have invested in education beyond the bachelor's level and, thus, indicate a quality need for professional improvement. This resonates with Lai and Jin's (2021) [23] findings that teachers have increasingly become more moved to develop their competencies, which is very fundamental to the improvement of pedagogical practices and long-term career prospects. Additionally, the 42% holding a bachelor's degree attests to a qualification that is ostensibly vital for entering the teaching profession, as reported by Salvan and Hambre (2020) [9], who also failed to see direct linkages with student outcomes. The presence of 12% with doctorate degrees, though small, highlights the significance of advanced qualifications in leadership and specialized research areas, which corresponds to Mishra and Koehler's (2022) framework on the significance of continuous professional development for teachers in adapting to emerging educational challenges. Thus, the educational attainment distribution indicates a promising trend of teachers striving for higher qualifications to enhance both personal and professional growth.

The distribution of respondents in terms of the number of years in teaching is presented in Fig 6.

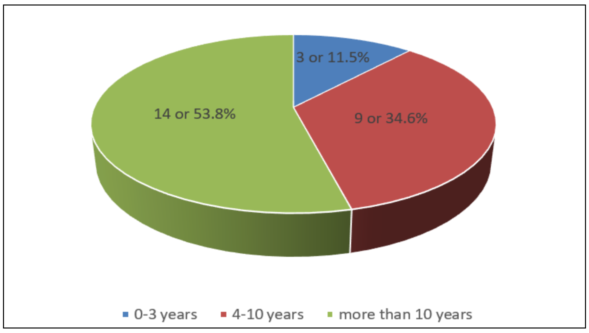

Fig 6: Distribution of Respondents by Number of Years in Teaching Science

Fig 6 is the spread of the responses given based on their experience in years. Here, 53.8 percent have been teachers for over 10 years. The results show that teachers possess many years of experience at this stage, having most of the experienced group as they had already had time. This team will also be knowledgeable with polished teaching, understanding student requirements, and perhaps even positive changes in their pedagogy. Long-term experienced practitioners often become mentees for trainee teachers in matters such as classroom management and curriculum design, together with how they can embrace a technological element for teaching.

34.6% fall within the 4-10 years, which may reflect a balanced distribution of mid-career teachers who have reached a point of experience in their teaching profession yet are still very open to learning and new strategies and professional development. These are the educators who happen to be in a career development stage where their practices are refined and are easy to work with innovations such as technology in the classroom. This group is very important for the continuous evolution of educational practices because they provide much-needed experience with openness to professional development.

The rest, 11.5% of the population, have experience ranging from 0 to 3 years of teaching, which still accounts for a sizeable minority of relatively recent additions to the profession. As they are relatively inexperienced, they could be worth hearing, at least insofar as their insight might be derived from their acquaintance with more modern pedagogic resources and technology-driven instruction. Newer teachers are more adaptable to innovations and may be more comfortable with incorporating technology into their teaching practices from the start of their careers. Their presence in the sample helps to balance the older, more experienced perspectives with fresh ideas and current trends in education.

The results from the distribution of respondents by years of teaching experience showed a significant range in expertise. A predominant 53.8% of teachers have over 10 years of experience. This shows that most of the teachers have developed experienced teaching skills, which allows them to understand the needs of the students and modify their pedagogy accordingly (Lai & Jin, 2021) [23]. In addition, the more experienced teachers are asked to mentor less experienced colleagues by giving them information about classroom management and curriculum design, including effective ways of incorporating technology (Nikolopoulou & Gialamas, 2015) [33]. The 34.6% of respondents falling in the 4-10 years category is a mid-career group of educators with honed skills who are also open to innovation, the bedrock of integrating new technologies into the classroom (Salvan & Hambre, 2020) [9]. This balance of experience with the willingness to adapt to new pedagogical approaches supports Lai and Jin's argument about professional development that would serve novice as well as veteran teachers' needs (2021). Second, 11.5% of the teachers have 0-3 years of experience. These teachers bring new views and feel at ease with the use of technology right at the beginning of their careers. Younger teachers tend to be more confident and receptive to tools involving technology (Nikolopoulou & Gialamas, 2015) [33]. The presence of this group complements the diverse range of perspectives in the sample to support a more comprehensive view of the adoption of technology in teaching practices. This also highlights the importance of targeted professional development that bridges the gap between novice and veteran teachers in terms of technology integration (Joshi, 2023) [21].

The distribution of respondents in terms of the number of seminars and trainings attended related to science is presented in Fig 7.

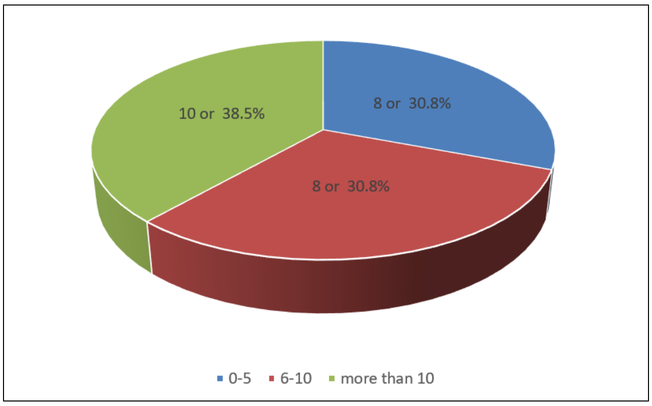

Fig 7: Distribution of Respondents by Number of Relevant Seminars and Training Attended

Fig 7 provides the distribution of respondents based on the number of relevant seminars and training that they have attended in the science field. This shows a fair level of variation in the uptake of professional development. 30.8% of the respondents have attended between 0 and 5 relevant seminars or training courses. This may, therefore, show that a sizeable proportion of the teachers had engaged in a moderate level of professional development. This group, while active in attending training, may have limited exposure to a broader range of specialized topics or recent advancements in the field. The relatively lower percentage in this category might reflect challenges such as time constraints, lack of available training, or competing professional responsibilities.

Another 30.8% of the respondents reported attending 6 to 10 relevant seminars or training courses, suggesting a moderately high level of professional engagement. Teachers in this category are probably bound to acquire the right knowledge and skills due to involvement in a mix of professional development activities. Probably, this category needs both theory and practical information as this may give them more confidence to put their newly gained knowledge into practice. Such teachers are normally in the stage of skill building, which places them in an excellent position to apply current pedagogical strategies and instructional technologies.

The biggest group, 38.5% of respondents, have attended more than 10 relevant seminars or training courses. This is an indicator of high engagement with ongoing professional development. Teachers in this category are likely to have gathered a lot of knowledge and experience, possibly keeping abreast of the latest trends, methodologies, and technologies in science education. Their frequent participation in training reflects a strong commitment to improving their practice and staying updated on innovations in the field. This high level of involvement in seminars and training can significantly influence the approach that would be used, as they will be more inclined to take in new strategies to be applied to their teaching environments, including embracing technology integration.

The study results show that there is a wide range of engagement in professional development, where most of the respondents attended 0 to 5 seminars, followed by 6 to 10, and a significant number (38.5%) attended more than 10. This distribution is in line with existing research, which underscores the role of professional development in teacher preparedness, especially on how to incorporate technology into teaching. Based on Lai and Jin (2021) [23], younger teachers are generally more confident and responsive to technology, and therefore, professional development should be focused on the different needs of teachers in terms of technology. Likewise, Nikolopoulou and Gialamas (2015) [33] argue that there should always be continuous, practical training in digital literacy; this may help improve the level of confidence and competence of teachers in the classroom. Thus, according to OECD (2021) [35], teachers need continuous professional development to be adequately trained to make the best use of technology in teaching. The variation in the number of seminars attended by the respondents in this study is important in the provision of targeted, accessible, and specialized courses to ensure teachers are adequately prepared to achieve integration of modern educational technology and methodologies.

Table 3: Available Technologies used by Science Teachers and the number of hours they are using each on a daily basis

Software	1-2 hrs	3-4 hrs	4-5 hrs	6-8 hrs	Total	
	f	*f*	*f*	*f*	*f*	%
Microsoft Word	11	7	3	2	23	88%
Microsoft Excel	16	5	1	1	23	88%
Microsoft Powerpoint Presentation	7	9	7	2	25	96%
Microsoft Teams	5	1	1	0	7	27%
Google Meet	12	0	0	0	12	46%
Zoom	8	1	0	0	9	35%
Google Classroom	9	1	0	0	10	38%
Edmodo	1	0	0	0	1	4%
Schoology	0	0	0	0	0	0
Google Forms	7	2	1	0	10	38%
Kahoot	3	0	0	0	3	12%
Quizlet	1	0	0	0	1	4%
Adobe Premier Pro	2	0	0	0	2	8%
Wondershare Filmora	1	0	0	0	1	4%
Capcut	3	1	0	0	4	15%
Paint	2	0	0	0	2	8%
Canva	8	0	1	0	9	35%
Email	7	4	1	0	12	46%
Messenger	7	9	3	3	22	85%
Youtube	16	3	2	0	21	81%
Hardware	*f*	*f*	*f*	*f*	*Total f*	%
Desktop Computer/Laptop	4	7	10	4	25	96%
Digital Camera	1	0	0	1	2	8%
Printer	13	7	1	1	22	85%
Scanner	12	2	0	1	15	58%
Projector	10	0	1	1	12	46%
Mobile Phone	3	7	10	2	22	85%
Flash Drive, CD, DVD	16	4	1	1	22	85%
TV	6	8	7	1	22	85%
Anycast	4	1	2	0	7	27%
Speakers	11	3	3	1	18	69%

Table 3 presents the technologies applied by science teachers and the hours spent on each per day. Of the software applications, Microsoft PowerPoint is the most popular, followed by Microsoft Word and Microsoft Excel, which demonstrate their flexibility and longstanding use in the teaching process. They are mainly applied for the preparation of teaching aids, data compilation, and conducting lessons. Microsoft Teams, Google Meet, and Zoom are used less by teachers and indicate a general preference for direct interpersonal contact over video conferencing. Google Classroom and Edmodo appear to be relatively underutilized, suggesting the possibility that teaching is still most cherished in the "old-fashioned way" of having a classroom versus using digital means to manage their classes.

Computer and laptop desktop computers account for the most usage, as each respondent reported daily use, often referring to these as essential tools for preparing and delivering lessons. Mobile phones also represent general applications such as notebooks, TVs, and flash drives/CDs/DVDs, as they produce materials and play multimedia content. However, the low use of digital cameras indicates that teachers may still prefer to create content using their smartphones or other devices. The results generally suggest that teachers prefer using familiar and easy-to-use technologies, whereas new or specific technologies are not widely adopted for various reasons such as training, resources, and the teacher's preference.

This study's implications indicate that science teachers are comfortable using a wide array of technologies; however, they tend to lean toward the familiarity of tools in support of the traditional methods in which they were trained. In turn, the choice of professional development programs would likely be better informed by providing training to make teachers more digitally literate with newer platforms and tools. There is also an opportunity to consider the underutilization of specialized technologies, like digital cameras, to see how they can be included in teaching strategies and enhance practical learning experiences. In some cases, schools and educational institutions may have to provide extra resources, training, and support for a balanced use of traditional and innovative technologies for teaching.

The results of this research align with existing literature on the beliefs and behaviors of instructors regarding the introduction of technology in their classrooms. As highlighted in Table 3, Microsoft PowerPoint, Word, and Excel are featured as the most frequently used applications of software. This would resonate with Francom (2019) [14] and the OECD (2021) [35], which pointed out that "well-known easy-to-use tools" were incredibly powerful in helping teachers become effective. These technologies are very popular for the preparation of teaching aids, compiling data, and delivery of lessons. According to the theory of Pedagogical Content Knowledge (PCK), teachers make use of tools that supplement their needs in instructional duties (Mishra & Koehler, 2006) [29]. The limited usage of specialty sites like Google Classroom and Edmodo indicates science teachers are content to use established resources, with support from Lai and Jin's (2021) [23] postulate that many veterans in teaching rely on well-known methods before exploring new digital media. The limited use of video conferencing tools such as Microsoft Teams, Google Meet, and Zoom reflects a broader pattern of hesitation about virtual learning environments, a point noted in research by Nikolopoulou and Gialamas (2015) [33], who showed that even older teachers were very reluctant to implement technology despite it being increasingly emphasized. Moreover, the use of desktop computers and laptops aligns with Francom's (2019) [14] conclusion on infrastructure issues, where teachers tend to use the resources they are most accustomed to. Lastly, the underutilization of digital cameras in this study indicates a lack of utilization of more advanced technologies for hands-on learning, which could be filled through targeted professional development programs (Lehiste, 2020; Jiménez Sierra *et al.*, 2023 [20]). This study emphasizes the necessity of professional training to boost the digital literacy of teachers, promoting the implementation of new technologies that could contribute to improving students' involvement and their academic outcomes (Koehler & Mishra, 2019) [29].

TPACK of Science Teachers

This part presents the TPACK level of science teachers as perceived by the two groups of respondents.

Table 4: Teachers' Technological Knowledge as perceived by the two groups of respondents

Indicators	Students		Teachers		Overall	
	Mean	DR	Mean	DR	Mean	DR
TK1. Science teachers can use technologies that enhance the teaching approaches for a lesson.	4.38	SA	4.92	SA	4.65	SA
TK2.Science teachers can choose technologies that enhance students' learning of a lesson.	4.26	SA	4.85	SA	4.56	SA
TK3. Science teachers can use technologies in various teaching activities.	4.16	A	4.77	SA	4.47	SA
TK4. Science teachers can think critically about the most appropriate technology that they can use in the classroom.	4.14	A	4.54	SA	4.34	SA
TK5.Science teachers can use technology to introduce the students to real-world scenarios.	4.13	A	4.69	SA	4.41	SA
TK6. Science teachers can facilitate students to use technology to find more information on their own.	4.02	A	4.54	SA	4.28	SA
TK7. Science teachers can facilitate students to use technology to plan and monitor their own learning.	3.87	A	4.46	SA	4.17	A
TK8. Science teachers can facilitate students to collaborate with each other using technology.	4.03	A	4.42	SA	4.23	SA
TK9. Science teachers can utilize technological tools to make teaching processes more productive.	4.17	A	4.54	SA	4.36	SA
TK10. Science teachers can use strategies that combine technology and teaching approaches in the classroom.	4.39	SA	4.69	SA	4.54	SA
Overall mean	4.16	H	4.64	VH	4.40	VH

Legend: 4.21-5.00 - Strongly Agree (SA) – Very High
3.41-4.20 – Agree (A) – High

The table above reflects the technological knowledge (TK) of science teachers as perceived by both students and teachers themselves. Overall, the findings indicate strong agreement on the part of both groups regarding the teachers' ability to integrate technology into their teaching practices.

As shown in Table 4, the highest statement rated by the students and the teachers is TK1, which states, "Science teachers can use technologies that enhance the teaching approaches for a lesson," scoring a mean value of 4.65 on all respondents and indicating a very high level of agreement. This means science educators are proficient in using technology to aid in the facilitation of learning. TK10, "Science teachers can use strategies that combine technology and teaching approaches in the classroom," was also rated highly by both groups, which again supports the hypothesis that science teachers are effective at integrating technology with pedagogical strategies to improve learning.

The least-rated statement is TK7, "Science teachers can facilitate students to use technology to plan and monitor their learning." For students, it has a mean of 3.87, while for teachers, it has a mean of 4.46; both groups agree but to a lesser extent as compared to other statements. This, therefore, means that despite science teachers having the capability to facilitate student-centered learning with technology, there is, perhaps, still some challenge or limitation in that it does not allow students the complete freedom and ability to design and conduct their plans of learning entirely using digital technologies.

The "Very High" general mean at 4.40 indicates overall agreement that the science teachers hold technological knowledge about effectively integrating it into their practices. Both respondent groups agree with this statement and reflect the level of technological literacy of science teachers. It can be inferred that science teachers have the necessary tools to apply technology in various aspects of teaching and learning, develop student learning, and foster a collaborative learning atmosphere. However, the slight differences in perceptions suggest that there may be some professional development or support needed in some areas, like the lower agreement on facilitating self-regulated learning through technology.

It shows that science teachers possess strong technological knowledge, yet efforts to strengthen their ability to help students develop independent learning using digital means should be continued. This can be achieved by adding more training to them on technology use for student-centered learning and promoting best practices in student autonomy in a tech-rich environment.

The outcomes of the study show that science teachers have a high level of TPACK; therefore, they can easily integrate information communication technology into their teaching activities. Overall, very high mean scores were obtained from both sets of respondents (students and teachers) that indicated that science educators are effectively using technology for the improvement of lesson delivery, effective facilitation of students' learning, and encouragement of collaborative learning. This is supported by Mishra and Koehler's (2006) [29] TPACK framework, which asserts the central significance of technology being integrated into pedagogy and content knowledge to enrich teaching. The most endorsed statement in terms of the utilization of technology for enhancing teaching methods (TK1), therefore, aligns with this and, as indicated by Beri and Sharma (2021) [5], points out the need to integrate technology with pedagogy to teach effectively. However, the lower rating on the facilitation of student-centered learning (TK7) indicates that although teachers can use technology, more professional development may be required to enhance their ability to guide students in self-regulated learning through digital tools, a challenge also noted by Francom (2019) [14] and Koehler and Mishra (2019) [29]. These findings call for further training in ways to help science teachers better support independent learning and foster the use of technology for student autonomy in learning.

Table 5: Teachers' Pedagogical Knowledge as perceived by the two groups of respondents

Indicators	Students		Teachers		Overall	
	Mean	DR	Mean	DR	Mean	DR
PK1. Science teachers know how to assess student performance in the classroom.	4.40	SA	4.73	SA	4.57	SA
PK2. Science teachers can adapt their teaching based on what students currently understand or do not understand.	4.16	A	4.73	SA	4.45	SA
PK3. Science teachers can adapt their teaching styles to different types of learners.	4.09	A	4.65	SA	4.37	SA
PK4. Science teachers can assess student learning in multiple ways.	4.18	A	4.50	SA	4.34	SA
PK5. Science teachers can use a wide range of teaching approaches in a classroom setting.	3.92	A	4.42	SA	4.17	A
PK6. Science teachers are familiar with common student understandings and misconceptions.	4.02	A	4.5	SA	4.26	SA
PK7. Science teachers can manage their classroom effectively.	4.11	A	4.65	SA	4.38	SA
PK8. Science teachers can recognize individual differences in students.	4.06	A	4.62	SA	4.34	SA
PK9. Science teachers can guide the students adopt appropriate learning strategies.	4.20	A	4.50	SA	4.35	SA
PK10. Science teachers can help the students monitor their own learning.	4.14	A	4.58	SA	4.36	SA
Overall Mean	4.13	H	4.59	VH	4.36	VH

Legend: 4.21-5.00 - Strongly Agree (SA) – Very High
3.41-4.20 – Agree (A) – High

The data in Table 5 gives valuable insights into science teachers' perceived pedagogical knowledge (PK) from both the students' and teachers' perspectives. General findings are indicative of a level of high overall pedagogical proficiency with each group recognizing teacher effectiveness in core areas of pedagogy.

The highest-rated statement in the student respondent's case was PK1 "Science teachers know how to assess student performance in the classroom, which has a mean of 4.40. This would mean that there was an obvious capability in terms of measuring the progress among students. Although PK5 scored relatively low with a mean of 3.92 on "Science teachers can use a wide range of teaching approaches in a classroom setting," this is still in the "Agree" category, showing that the teachers' capacity to use different teaching approaches was viewed positively but not very enthusiastically.

Teacher respondents score an overwhelmingly high level of agreement on all indicators of pedagogical knowledge, at a mean score of 4.59, classified as "Very High." Again, PK1 is the top scorer with a mean of 4.73, which shows that teachers believe in their judgment of students' performance and are very confident in judging the performance accurately and effectively. The consistency of responses reflects that there is great internal alignment and confidence among teachers toward their pedagogical skills.

One of the more interesting findings is that on PK5, there is relatively low agreement, perhaps indicating that even though teachers may be adept in using several methods, there is further scope for learning or diversifying teaching approaches within certain settings. Perhaps this could highlight the need for further professional development, particularly concerning the adaptation of teaching strategies for the increasingly varied needs of the students.

The overall mean of 4.36, categorized as "Very High," further strengthens the robust pedagogical foundation among science teachers, as both groups consistently rate them highly. However, the slight difference in ratings between students and teachers, especially in the use of diverse teaching methods, may suggest a difference in perspective. Teachers may also believe that their strategies are more effective than those perceived by students, indicating that the latter lack experience or exposure to the gamut of approaches employed in class.

The high agreement scores over pedagogical knowledge point to the fact that it reflects a sturdy teaching environment where assessment, classroom management, and recognition of differences exist among students. Even further, it can be helpful to enhance pedagogical effectiveness by identifying strategies for incorporating more diverse and creative teaching methods so that all different types of students are ensured access to various kinds of instruction tailored to their learning needs.

The outcome of Table 5 is that science teachers, according to students and teachers alike, possess strong levels of pedagogical knowledge, although there are minor differences between perceptions, which is still a source for improvement. There is a highly rated teacher effectiveness among both in matters of assessing performance of students as well as altering the teaching styles for diverse learners. For example, the most endorsed assertion, "Science teachers know how to assess student performance," elicited a mean score of 4.40 among students and 4.73 among teachers, which was a strong sense of confidence by teachers in being able to assess student learning (Mishra & Koehler, 2006) [29]. Still, it had a tiny gap in how the students responded to the question about the variation of teaching method use, recording a mean student score of 3.92 on the statement "Science teachers can use a wide range of teaching approaches", implying that they might not wholly acknowledge or benefit from the varieties of methods, as perceived by teachers (Francom, 2019) [14].". This result agrees with Salvan and Hambre (2020) [9], who identified professional development as the means through which teachers could enhance their teaching strategies in adjusting to the various needs of their students. Further, the outcome of this study reveals that although the respondents have a feeling of security and competence in their classrooms, concerning student diversity, more professional development on diverse instructional approaches is required to maximize the effectiveness of teaching (Koehler & Mishra, 2019) [29]. These findings emphasize the need for continuous, targeted training that enhances teachers' pedagogical skills while considering students' feedback to create more inclusive and varied teaching strategies (Mishra & Koehler, 2022).

Table 6: Teachers' Content Knowledge as perceived by the two groups of respondents

Indicators	Students		Teachers		Overall	
	Mean	DR	Mean	DR	Mean	DR
CK1. Science teachers have sufficient knowledge about science.	4.46	SA	4.92	SA	4.69	SA
CK2. Science teachers can use and apply scientific ways of thinking.	4.32	SA	4.85	SA	4.59	SA
CK3. Science teachers have various ways and strategies of developing their understanding of science.	4.29	SA	4.77	SA	4.53	SA
CK4. Science teachers can think about the content of science like a subject matter expert.	4.25	SA	4.54	SA	4.40	SA
CK5. Science teachers have a deep and wide understanding of biology.	4.37	SA	4.69	SA	4.53	SA
CK6. Science teachers have a deep and wide understanding of chemistry.	4.43	SA	4.54	SA	4.49	SA
CK7. Science teachers have a deep and wide understanding of earth science.	4.45	SA	4.46	SA	4.46	SA
CK8. Science teachers have a deep and wide understanding of physics.	4.37	SA	4.42	SA	4.40	SA
CK9. Science teachers are following up-to-date resources (e.g., books, journals) in their content area.	4.12	A	4.54	SA	4.33	SA
CK10. Science teachers are following recent developments and applications in their content area.	4.27	SA	4.69	SA	4.48	SA
Overall Mean	4.33	VH	4.64	VH	4.49	VH

Legend: 4.21-5.00 - Strongly Agree (SA) – Very High
3.41-4.20 – Agree (A) – High

The results as reflected in Table 6 reveal a strong consensus among the student-respondents, with all statements receiving a "strongly agree" descriptive rating except for CK9 statement "Science teachers are following up-to-date resources (e.g., books, journals) in their content area", which has a mean of 4.12. The overall mean of 4.33 suggests that almost all students have a strong positive perception of their science teachers. However, some of the respondents have deviated from the general perception, which means that their view on their teachers' use of up-to-date resources is not that high.

Table 6 also conveys that science teachers perceived themselves as effectively possessing each of the content knowledge as indicated above. The overall mean of 4.64 clearly shows that science teachers are confident in their content knowledge.

The overall mean of 4.49 for content knowledge based on the perceptions of the two groups of respondents shows that both the students and the science teachers themselves are confident about the content knowledge of the teachers.

The outcomes suggest that although science teachers are generally well-qualified on the content level, there are opportunities for advancement in keeping updated with the new resources and knowledge of science advancements. The lowest rating for CK9 indicates that teachers might require continuous professional development and ready access to newly published teaching materials, thereby ensuring current research, emerging technologies, and relevant resources inside their classrooms. The use of up-to-date resources could be further enhanced to enrich the learning experience of students, making science education more relevant and engaging. This also underlines the need for teachers to seek new materials and interact with the wider scientific community to maintain a dynamic and cutting-edge learning environment.

The results of Table 6 indicate that students and teachers generally consider science educators highly knowledgeable in most fields, with a strong consensus overall concerning the CK of the teachers. Even as science teachers are relatively confident about their knowledge of biology, chemistry, earth science, and physics, the slightly lower rating for CK9, which focuses on the usage of updated materials, indicates that there is still some scope for improvement in maintaining access to current research and resources. This is consistent with Lai and Jin's (2021) [23] assertion that teachers should continually be updated on the latest emerging technologies and research to improve their instructional practices, as proposed by Salvan & Hambre (2020) [9]. The research conducted by Francom (2019) [14] further indicates that some of the challenges include limited resources and inadequate training that hinder technology integration, thereby highlighting the role of institutional support in filling the gaps. Thus, providing science teachers with regular access to up-to-date resources is essential for fostering a dynamic and engaging learning environment that meets the evolving needs of both educators and students.

Table 7: Overall Mean of TPACK Level of Science Teachers Based on Students' and Teachers' Point of View

	Student		Teacher		Overall	
	Mean	**DR**	**Mean**	**DR**	**Mean**	**DR**
Technological Knowledge	4.16	A	4.64	SA	4.40	SA
Pedagogical Knowledge	4.13	A	4.59	SA	4.36	SA
Content Knowledge	4.33	SA	4.64	SA	4.49	SA
Overall	4.21	SA	4.62	SA	4.42	SA

Legend: 4.21-5.00 - Strongly Agree (SA) – Very High
3.41-4.20 – Agree (A) – High

Table 7 reveals the comparison of TPACK levels of science teachers from the students' and teachers' perspectives. The results show that the two groups differ significantly in how they perceive the competencies of the teachers in all areas.

Students' responses under Technological Knowledge have a mean of 4.16, falling in the "Agree" range. This means that students feel that the teachers teach well with technology, indicating a positive perception of the teachers' ability to integrate technology into their instruction. The teachers' response to themselves was significantly high, with a mean of 4.64, which corresponds with a "Strongly Agree" rating. This difference indicates that teachers feel more confident in their technological abilities than the students perceive them to be.

Similarly, Pedagogical Knowledge received a mean of 4.13 from students, which also indicates an agreement that teachers possess strong pedagogical skills. Teachers rated themselves at 4.59, reflecting a higher self-assessment and suggesting that teachers feel even more assured of their teaching strategies and methods.

For Content Knowledge, both groups expressed strong agreement on the options. Students rated it at 4.33 (Strongly Agree), while teachers rated it at 4.64 (Strongly Agree). This indicates that both students and teachers have a very high level of confidence about the skills/competencies of the teachers with regard to the science subjects.

Student respondents' perception average was at 4.21, falling within the "Strongly Agree" level, but teacher self-report fell to 4.62 and was further along the continuum than the former's overall rating about the TPACK competency. With the combined average standing at 4.42, this, therefore, demonstrates a consonant alignment concerning the two groups whereby teachers' proficiency over technological, pedagogical, and content knowledge is highly positively perceived by all.

The findings are positive on teachers' TPACK but show a gap in perception, mainly in Technological and Pedagogical Knowledge, where the teachers were perceived to have better competencies by themselves as opposed to how they were rated by the students. This might mean that the self-assessment is overrated for the teachers or that these skills are seen differently by students when applied in practice. High agreement on Content Knowledge means both perceive teachers as being competent in the subject areas.

These findings suggest that teachers might gain feedback regarding how to effectively integrate technology and pedagogy in ways that can be more readily identified by the students. Professional development aimed at improving these areas could bridge the gap between self-assessments by teachers and perceptions by students to improve teaching effectiveness.

According to Mishra and Koehler (2006) [29], effective teaching requires the integration of technology, pedagogy, and content knowledge, but teachers' overestimation of their technological and pedagogical abilities suggests a need for more targeted training and reflection. Furthermore, studies conducted by Mai and Hamzah (2016) [26] and Valtonen *et al*. (2020) [45] suggest that pedagogical skills form the basis for the integration of technology, indicating that enhancing pedagogical skills is crucial for filling the gap between self-assessment and perception by students. The findings are in line with the recommendations of Beri and Sharma (2021) [5], which state that customized professional development can improve teachers' TPACK competencies, leading to better alignment between self-perception and actual classroom application. Moreover, Francom (2019) [14] suggests that removing barriers to technology integration is essential; he further adds that enhancing resources and teacher training can help bridge the gap between teacher confidence and student experiences. Thus, the findings call for continuous professional development and reflective practices to help teachers become effective at integrating technology and pedagogy in the process of improving students' learning outcomes.

Table 8: Difference Between Students' and Teachers' Perceptions of the TPACK Level of Science Teachers

	t-value	p-value	Interpretation
Technological Knowledge	-7.418	0.000	Significant
Pedagogical Knowledge	-5.575	0.000	Significant
Content Knowledge	-1.518	0.139	Not Significant
Overall	-5.525	0.000	Significant

Table 8 highlights a substantial difference in the perception of students and teachers regarding science teachers' technological knowledge (TK) and pedagogical knowledge (PK). The significant difference suggests that students and teachers diverge in their views on these aspects.

Conversely, the p-value of 0.139 for content knowledge (CK) indicates an insignificant difference in the perceptions of students and teachers. This suggests a relatively consistent alignment on how both groups perceive the content knowledge of science teachers, with the lack of statistical significance implying a similarity in their perceptions.

The results show that there is consensus on the Content Knowledge of science teachers, but there are considerable differences in perceptions of Technological and Pedagogical Knowledge. Such differences could be due to different expectations or experiences between students and teachers. Students may not always recognize the pedagogical strategies or technological tools used in teaching, while teachers may overestimate their effectiveness in these areas. This gap may be addressed through targeted professional development in the use of technology and pedagogy. This could effectively align both perspectives, hence strengthening teaching practices and student outcomes.

The overarching conclusion is that while there's congruence in the perceptions of students and teachers regarding content knowledge, there is a noteworthy discrepancy in their technological and pedagogical knowledge. This underscores the importance of addressing and bridging these perceptual gaps for more comprehensive and effective educational strategies tailored to the specific needs of each group.

According to Lai and Jin (2021) [23], the study highlighted the technology integration generational gap, thereby indicating that technology use is far more confident by novice teachers rather than their experienced counterparts. It is also true that Nikolopoulou and Gialamas (2015) [33] mentioned the fact that junior teachers are highly confident in comparison to their veteran counterparts. These findings indicate a pressing need for focused professional development on these topics as well as better alignment between what students and teachers understand about technology and pedagogy. In addition, with no significant variations in CK, it implies consensus on the nature of content expertise of science teachers, which accords with research findings by Mai and Hamzah (2016) [26], highlighting that pedagogical content knowledge is foundational in teaching, yet its integration into technology is one of the key challenges.

Table 9: Relationship between Profile and TPACK level of Science Teachers

	Technology		Pedagogy		Content		Overall	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Age	0.003	0.987	0.164	0.424	-0.13	0.527	-0.016	0.936
Sex	0.016	0.936	0.235	0.248	0.195	0.34	0.151	0.461
Education	0.287	0.155	0.31	0.123	0.282	0.162	0.334	0.096
Number of years in teaching	-0.008	0.968	0.06	0.773	-0.097	0.636	-0.037	0.869
Number of seminars & trainings	0.153	0.455	0.383	0.054	0.276	0.172	0.336	0.093
Microsoft Word	0.288	0.153	0.289	0.152	0.155	0.451	0.285	0.159
Microsoft Excel	0.404*	0.041	0.316	0.116	0.346	0.083	0.416*	0.035
Microsoft Powerpoint Presentation	0.580**	0.002	0.408*	0.039	0.346	0.084	0.513**	0.007
Microsoft Teams	0.378	0.057	0.468*	0.016	0.518**	0.007	0.544**	0.004
Google Meet	0.486*	0.012	0.332	0.097	0.256	0.208	0.412*	0.037
Zoom	0.384	0.053	0.093	0.651	0.102	0.620	0.211	0.301
Google Classroom	0.370	0.063	0.147	0.472	0.181	0.377	0.263	0.195
Edmodo	0.029	0.887	0.296	0.143	0.298	0.139	0.261	0.197
Schoology	0.104	0.615	0.085	0.681	0.035	0.864	0.085	0.678
Google Forms	-0.128	0.535	-0.005	0.981	0.070	0.735	-0.015	0.941
Kahoot	-0.091	0.658	-0.021	0.920	-0.051	0.803	-0.061	0.768
Quizlet	0.105	0.610	0.111	0.589	0.130	0.527	0.137	0.504
Adobe Premier Pro	0.248	0.222	0.236	0.245	0.188	0.358	0.262	0.195
Wondershare Filmora	0.105	0.610	0.111	0.589	0.130	0.527	0.137	0.504
Capcut	0.024	0.909	-0.051	0.805	-0.036	0.863	-0.029	0.889
Paint	-0.137	0.505	0.198	0.331	0.150	0.466	0.102	0.622
Canva	-0.049	0.811	0.063	0.761	-0.058	0.779	-0.014	0.944
Email	0.080	0.699	0.257	0.204	0.191	0.350	0.217	0.288
Messenger	-0.059	0.775	0.045	0.826	0.233	0.252	0.098	0.634
Youtube	0.068	0.741	0.158	0.440	0.389*	0.049	0.254	0.210
Desktop Computer/Laptop	0.403*	0.041	0.255	0.209	0.316	0.116	0.376	0.058
Digital Camera	0.063	0.758	0.123	0.549	0.172	0.400	0.146	0.476
Printer	0.403*	0.041	0.188	0.358	0.175	0.392	0.288	0.153
Scanner	0.224	0.272	0.446*	0.022	0.562**	0.003	0.501**	0.009
Projector	0.104	0.612	0.126	0.539	0.147	0.474	0.150	0.463
Mobile Phone	0.062	0.764	0.088	0.669	0.329	0.101	0.197	0.335
Flash Drive, CD, DVD	0.173	0.397	0.375	0.059	0.397*	0.045	0.385	0.052
TV	-0.022	0.916	0.131	0.523	0.290	0.151	0.171	0.404
Anycast	0.172	0.400	0.175	0.392	0.476*	0.014	0.333	0.097
Speakers	0.213	0.295	0.354	0.076	0.424*	0.031	0.401*	0.043
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

Table 9 indicates that demographic factors such as age, sex, educational attainment, years in teaching and number of relevant seminars/training attended are not significantly correlated with the teachers' TPACK. However, there is a noteworthy relationship between specific software usage and teachers' TPACK, with significance at the 0.05 level and 0.01. Microsoft Excel and Google Meet are significantly correlated with teachers' TK at a 0.05 level of significance, while Microsoft PowerPoint presentation is significantly linked with TK at a 0.01 level of significance. Furthermore, the Microsoft PowerPoint presentation is also significantly correlated with PK at a 0.05 level of significance. Microsoft Teams and YouTube are significantly correlated with CK at 0.01 and 0.05 levels of significance, respectively. This suggests that the extent to which teachers use the abovementioned software is associated with their technological, pedagogical, and content knowledge.

Furthermore, hardware usage is significantly linked with content knowledge with significance at the 0.05 level. Desktop computer/laptop, printer, scanner, flash drive, anycast, and speaker show a significant relationship with TPACK at a 0.05 level of significance. This implies that the utilization of the aforementioned hardware is specifically associated with the technological, pedagogical, and content knowledge of science teachers.

Overall, the results emphasize that technology use, both in terms of software and hardware, is significantly related to the overall TPACK of teachers. This accentuates the importance of integrating technology, including both software and hardware, in enhancing teachers' proficiency in technological, pedagogical, and content knowledge.

The results of the study show that the relationship between science teachers' demographic characteristics and their TPACK levels is complicated, with particular emphasis on software and hardware usage. The findings that age, sex, educational attainment, years of teaching, and seminar participation were not significantly correlated with TPACK agree with previous works, such as Lai and Jin (2021) [23], who argued that demographic factors often did not predict the integration of technology into the teaching practices of teachers. This implies that age or years of teaching experience may not be as significant as assumed, thus challenging the assumption that experience is the most important factor in technology adoption. On the other hand, the strong relationships between software usage, such as Microsoft PowerPoint and Google Meet, and TPACK dimensions like technology knowledge (TK) and pedagogical knowledge (PK) indicate that specific technological tools are crucial for improving teachers' instructional practices. Francom (2019) [14] and the OECD (2021) [35] also have similar findings regarding the role that digital tools can play in developing teachers' pedagogical capacity when used together with technology. Additionally, a significant relationship was found between the use of hardware (such as desktop computers, printers, and scanners) and CK because hands-on practice with technology encourages greater involvement with content presentation (Jiménez Sierra *et al*., 2023) [20]. These findings call for targeted professional development programs that focus not only on the demographic characteristics of teachers but also on their engagement with both software and hardware tools, as suggested by Mishra and Koehler (2006) [29], whose TPACK framework highlights the critical integration of technology with pedagogy and content to foster effective teaching and learning. Thus, the findings of this study only call for strategic investment in technology training and infrastructure to improve teachers' overall TPACK, which would improve their instructional effectiveness.

4. Conclusion

Based on the salient findings of the study, the following can be concluded.

1. Most teachers are female. Most of them exhibit high levels of energy, enthusiasm, and adaptability because they are generally young. The wealth of experience and continuous professional development emphasizes their effort of leveraging their expertise to enhance the quality of teaching and adapt to evolving educational trends.
2. Most of the Science teachers utilize desktop/laptop, mobile phone, and Microsoft PowerPoint presentations in their teaching.
3. Students and science teachers have similar views on content knowledge of science teachers while their views on the technological and pedagogical knowledge diverge.
4. The Science teachers' age, sex, educational attainment, number of years in teaching, and number of seminars/training attended does not influence their TPACK.
5. The correlation between technology use and TPACK of science teachers underscores the significance of technology integration in modern science education.

5. Recommendations

With the conclusions drawn from the study, the following recommendations are forwarded.

1. Science teachers should continue their graduate studies to enhance their competencies and skills in teaching. Participation in seminars and training related to the field is also encouraged.
2. Teachers should continue exploring other technologies that would enhance their teaching and students' learning.
3. Headteachers and Master teachers should continuously aid teachers, especially in preparing their lessons to ensure that the TPACK of teachers is at the level where they can contribute to the delivery of quality education.
4. The results of this study shall be disseminated to the teacher-respondents.

The DepEd should continuously provide opportunities for teachers to attend training related to technology use as it affects their TPACK level.

6. References

1. Adams C. TPACK Model: The Ideal Modern Classroom. Pressbooks.pub, 2019. https://pressbooks.pub/techandcurr2019/chapter/tpack-modern-classroom/
2. Agustini K, Santyasa IW, Ratminingsih NM. Analysis of Competence on "TPACK": 21st Century Teacher Professional Development. Journal of Physics: Conference Series. 2019; 1387:012035. Doi: https://doi.org/10.1088/1742-6596/1387/1/012035
3. Akturk A, Ozturk H. Teachers' TPACK Levels and Students' Self-efficacy as Predictors of Students' Academic Achievement. International Journal of Research in Education and Science (IJRES). 2019; 5(1):283-294. https://files.eric.ed.gov/fulltext/EJ1197990.pdf
4. Altun T, Akyıldız S. European Journal of Education Studies Investigating Student Teachers' Technological Pedagogical Content... ResearchGate, 2017. Doi: https://doi.org/10.5281/zenodo.555996
5. Beri N, Sharma L. Development of TPACK for teacher-educators. Linguistics and Culture Review. 2021; 5(S1):1397-1418. Doi: https://doi.org/10.21744/lingcure.v5ns1.1646
6. Boholano H. Smart social networking: 21st century teaching and learning skills. Research in Pedagogy. 2017; 7(1):21-29.
7. Boholano HB, Cajes RC, Boholano GS. Technology based teaching and learning in junior high school. Research in Pedagogy. 2021; 11(1):98-107.
8. Boholano HB, Theodore V, Pogoy AM, Alda R. Technology-enriched teaching in support of quality education in the 21st century skills. Solid State Technology. 2020; 63(5):6795-6804.
9. Salvan C, VJ M, Hambre M. Teachers' Demographic Profile on the Learners' Performance Using K-12 Earth and Space module. Journal of Education & Social Policy. 2020; 7(4). Doi: https://doi.org/10.30845/jesp.v7n4p14

10. Celik I. Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. Computers in Human Behavior. 2023; 138(138):107468. Doi: https://doi.org/10.1016/j.chb.2022.107468
11. Chai CS. Teacher professional development for science, technology, engineering and mathematics (STEM) education: A review from the perspectives of technological pedagogical content knowledge (TPACK). The Asia-Pacific Education Researcher. 2019; 28(1):5-13. Doi: 10.1007/s40299-018-0400-7
12. Chatmaneerungcharoen S. Improving Thai science teachers' TPACK through an innovative continuing professional development program. In Journal of Physics: Conference Series. IOP Publishing, October 2019; 1340(1):p012017.
13. Filina NZ, Sari SM, Zahraini Z. The utilization of Technological Pedagogical Content Knowledge (TPACK) in elementary school learning. International Journal of Business, Law, and Education. 2024; 5(1):260-266. Doi: https://doi.org/10.56442/ijble.v5i1.371
14. Francom GM. Barriers to technology integration: A time-series survey study. Journal of Research on Technology in Education. 2019; 52(1):1-16. Doi: https://doi.org/10.1080/15391523.2019.1679055
15. Ghavifekr S, Wan Athirah WR. Teaching and learning with technology: Effectiveness of ICT integration in schools. International Journal of Research in Education and Science (IJRES) 2015; 1(2):175-191.
16. Gonzales A. Exploring Technological, Pedagogical, and Content Knowledge (TPACK) and Self Efficacy Belief of Senior High School Biology Teachers in Batangas City, 2018. https://www.palawanscientist.org/tps/wp-content/uploads/2018/07/3_Gonzales_-Palawan-Scientist_2018.pdf
17. Herring M, Koehler MJ, Mishra P. (Eds.). Handbook of technological pedagogical content knowledge (2nd edition). Mew York: Routledge, 2016.
18. Hunutlu Ş, Küçük S. Examining EFL Teachers' TPACK Perceptions, Web 2.0 Tools Usage, Workload, and Technostress Levels. International Journal of Computer-Assisted Language Learning and Teaching. 2022; 12(1):1-19. Doi: https://doi.org/10.4018/ijcallt.315306
19. Irwanto I, Redhana IW, Wahono B. Examining Perceptions of Technological Pedagogical Content Knowledge (TPACK): A Perspective from Indonesian Pre-service Teachers. Jurnal Pendidikan IPA Indonesia. 2022; 11(1):142-154. Doi: https://doi.org/10.15294/jpii.v11i1.32366
20. Jiménez Sierra ÁA, Ortega Iglesias JM, Cabero-Almenara J, Palacios-Rodríguez A. Development of the teacher's technological pedagogical content knowledge (TPACK) from the Lesson Study: A systematic review. Frontiers in Education. 2023; 8. Doi: https://doi.org/10.3389/feduc.2023.1078913
21. Joshi SB. TPACK and Teachers' Self-Efficacy: A Systematic Review. Canadian Journal of Learning and Technology. 2023; 49(2):1-23. Doi: https://doi.org/10.21432/cjlt28280
22. Koehler MJ, Mishra P. Introducing Technological Pedagogical Content Knowledge. In AACTE Committee on Innovation and Technology (Eds.), Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators. New York Routledge. - References - Scientific Research Publishing. (2015), 2008, 3-29. Scirp.org. https://www.scirp.org/reference/referencespapers?referenceid=1565931
23. Lai C, Jin T. Teacher professional identity and the nature of technology integration. Computers & Education. 2021; 175:104314. Doi: https://doi.org/10.1016/j.compedu.2021.104314
24. Lehiste P. The Impact of a Professional Development Program on In-Service Teachers' TPACK: A Study From Estonia. Problems of Education in the 21st Century. 2015; 66(1):18-28.
25. Lehtinen A, Niemen P, Viiri J. Pre-service teachers' TPACK beliefs and attitudes toward simulations. Contemporary Issues in Technology and Teacher Education. 2016; 16(2):151-171. https://www.learntechlib.org/primary/p/161874/
26. Mai MY, Hamzah M. Primary science teachers' perceptions of technological pedagogical and content knowledge (TPACK) in Malaysia. European Journal of Social Science Education and Research. 2016; 3(2): 167-179.
27. Martin B. Successful implementation of TPACK in teacher preparation programs. International Journal on Integrating Technology in Education. 2015; 4(1):17-26. Doi: https://doi.org/10.5121/ijite.2015.4102
28. Mercado NL, Panganiban JM, Ramos MI. Technology integration in teaching science using TPACK among pre-service science teachers of St. Bridget College, Batangas City, Philippines. Panganiban, Vivien and Myriene I. Ramos, Tricia, Technology Integration in Teaching Science Using Tpack among Pre-Service Science Teachers of St. Bridget College, Batangas City, Philippines (March 30, 2019). Jeryll Nicko L. Mercado, Vivien Joy M. Panganiban, Tricia Myriene I. Ramos, 2019, 63-71.
29. Mishra, Koehler. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Teacher College Record, Columbia University, 2006.
30. Mishra P. Considering contextual knowledge: The TPACK diagram gets an upgrade, 2019, 76-78. Doi: https://doi.org/10.1080/21532974.2019.1588611
31. Mohamad FS. Technological pedagogical content knowledge (TPACK) and the teaching of science: Determiners for professional development. Studies of Applied Economics. 2021; 39(1).
32. Muhaimin M, Habibi A, Mukminin A, Saudagar F, Pratama R, Wahyuni S, *et al*. A sequential explanatory investigation of TPACK:: Indonesian science teachers' survey and perspective. JOTSE. 2019; 9(3):269-281.
33. Nikolopoulou K, Gialamas V. Barriers to the integration of computers in early childhood settings: Teachers' perceptions. Education and Information Technologies. 2015; 20:285-301.
34. Noguera Fructuoso I. How millennials are changing the way we learn: The state of the art of ICT integration in education, Revista Iboeroamericana de Educación a Distancia. 2015; 18(1):45-65
35. OECD. TALIS 2021 Results. OECD Publishing, 2021. https://www.oecd.org/content/dam/oecd/en/publications

/reports/2021/09/education-at-a-glance-2021_dd45f55e/b35a14e5-en.pdf
36. OECD. TALIS 2021 Results. OECD Publishing, 2021. https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/09/education-at-a-glance-2021_dd45f55e/b35a14e5-en.pdf
37. Olofson M, Swallow M, Neumann M. TPACKing: A constructivist framing of TPACK to analyse teachers' construction of knowledge. Computers & Education. 2016; 95:188-201. Doi: 10.1016/j.compedu.2015.12.010
38. Özgür H. Relationships between teachers' technostress, technological pedagogical content knowledge (TPACK), school support and demographic variables: A structural equation modeling. Computers in Human Behavior. 2020; 112:106468. https://doi.org/10.1016/j.chb.2020.106468
39. Palmares MP, Batisla-Ong SN. Technological, Pedagogical, Content Knowledge (TPACK) of Science Teachers: Basis of In-Service Training Design Development. Cosmos Journal of Engineering & Technology. 2023; 13(1):1-15. Doi: https://doi.org/10.46360/cosmos.et.620231001
40. Ramos RA, Babasa EE, Vergara IB, Manalo BI, Gappi LL, Morfi TG. The TPACK confidence of preservice teachers in selected philippine teacher education institutions. International Journal of Education, Psychology and Counselling. 2020; 5(37):196-205.
41. Rone NA, Amor N, Jr J, Jeffry Morilla Saro. Students' Lack of Interest, Motivation in Learning, and Classroom Participation: How to Motivate Them? ResearchGate; Taylor & Francis, March 20, 2023. https://www.researchgate.net/publication/369370919_Students
42. Schweighofer P, Grünwald S, Ebner M. Technology enhanced learning and the digital economy. A literature review, International Journal of Innovation in the Digital Economy. 2015; 6(1):50-62.
43. Scott Kristin. A Review of Faculty Self-Assessment TPACK Instruments (January 2006 – March 2020). International Journal of Information and Communication Technology Education. 2021; 17:118-137. Doi: 10.4018/IJICTE.2021040108
44. Siedlecki SL. Understanding descriptive research designs and methods. Clinical Nurse Specialist. 2020; 34(1):8-12.
45. Valtonen T, Leppänen U, Hyypiä M, Sointu E, Smits A, Tondeur J. Fresh perspectives on TPACK: Pre-service teachers' own appraisal of their challenging and confident TPACK areas. Education and Information Technologies. 2020; 25(4):823-2842.
46. Zeng Y, Wang Y, Li S. The relationship between teachers' information technology integration self-efficacy and TPACK: A meta-analysis. Frontiers in Psychology. 2022; 13. Doi: https://doi.org/10.3389/fpsyg.2022.1091017