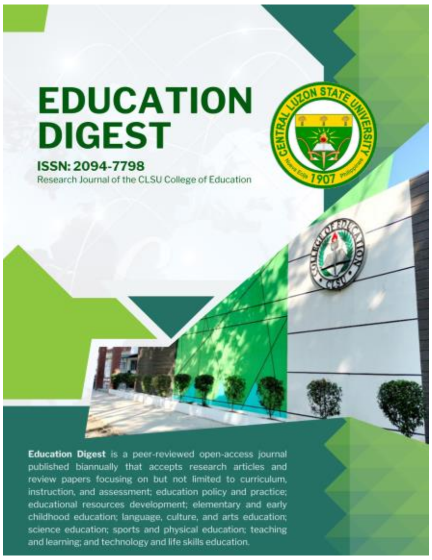

Examining technological, pedagogical, and content knowledge and instructional challenges of high school science teachers in Cabanatuan City, Philippines

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Abstract: This study examined public junior high school science teachers' technological, pedagogical, and content knowledge (TPACK) and instructional challenges. It aimed to determine the TPACK profile of the respondents and the challenges they encounter in teaching. This study was conducted in seven public junior high schools with 35 respondents in the Division of Cabanatuan City. It used a descriptive-correlational research design, including a survey questionnaire and data analysis using descriptive and inferential statistics. The findings revealed that the teachers have very satisfactory TPACK, with technological and content knowledge scoring highly and pedagogical knowledge outstanding in some areas. Challenges included insufficient training, lack of learning materials, and inadequate infrastructure, though respondents did not struggle with understanding science concepts. Teachers also reported issues such as insufficient preparation for laboratory activities, difficulties engaging students in discussions, and challenges in assessing students' capabilities. Significant relationships were found between respondents' age and instructional challenges with TPACK. Additionally, age and years of experience were significantly related to instructional challenges. The findings highlight the need for improved teacher training and resources to enhance instructional practices and support effective science education. This study provides valuable insights into the current state of science education in Cabanatuan City, offering a framework to improve teacher competencies through targeted training and resource provision. This may guide educational stakeholders in designing interventions to enhance teacher performance and foster a more engaging and supportive learning environment for students.

Keywords: *classroom challenges, pedagogical innovation, science education, teacher qualifications, TPACK*

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Introduction

Because of its significance in students' lives and the broad range of problem-solving and critical-thinking skills it cultivates, science is one of the most important subjects taught in schools (García-Carmona, 2023; Natividad, 2022). These lifetime skills help students generate ideas, make informed judgments, and understand the evidence supporting public policy. Through teaching technical literacy, problem-solving skills, and critical thinking, science equips students with the information and skills necessary to succeed in school and beyond (Santos, 2017). This is the reason why schools in most countries around the world give importance to science education. Based on Batomalaque (2002), science is usually seen as very important in the Philippines because of its links to technology and industry, which may be areas of high national importance for development. So, science is taught as a core topic in elementary and secondary school, even if it is conceptually complicated and expensive to administer (Kahana & Tal, 2014). Another argument favoring science taught in schools is that all individuals must acquire a certain level of "scientific literacy" to engage in contemporary society as citizens.

However, studies have found that students have difficulties learning science, resulting in low academic performance. The primary reasons include students' lack of science culture and shortcomings among their scientific weaknesses relating to the school's curriculum, how people learn and teach, and the teaching and learning process training for teachers. For this reason, the country had a shift in its education curriculum. The Philippines began using a new curriculum in the academic year of 2012-2013. This is when the new K to 12 curriculum replaces the Basic Education curriculum. Republic Act 1033, also known as the Enhanced Basic Education 2013, legalized the aforementioned innovation in Philippine education. Numerous changes have been made to the curriculum, such as extending the number of years students attend. It has been changed to 12 years from the previous 10-year program, Grades 1 to 10. Among the several fields or areas, science is subjected to significant modifications (Montebon, 2014).

The 2013 Philippine Curriculum Guide for Grades K to 12 states that the primary goal of the science curriculum is to create people who are scientifically literate, capable of making responsible decisions, knowledgeable members of society, and able to use scientific information that will significantly affect our society and the environment. In particular, the scientific curriculum aims to improve students' proficiency in three areas. These include using scientific methods and procedures, understanding and applying scientific data, and developing scientific attitudes and beliefs. The survey questions used in this study were created using these learning domains as a guide. The K to 12 curriculum aims to develop students with the following skills: critical/creative problem solver, responsible steward of nature, innovative or inventive thinker, informed decision maker, and effective communicator. Enhancing the different learning domains is how this is accomplished. In line with the curriculum change that happened, it is also a must that the teachers' Technological Pedagogical Content Knowledge (TPACK) be upgraded through a series of training and capacity building to enable them to become more effective facilitators of learning under the newly implemented curriculum. Mishra and Koehler (2006) introduced the concept of technological pedagogical content knowledge, or TPACK, as a framework for understanding the teacher knowledge needed to teach using ICT.

It cannot be denied that TPACK is a vital aspect that should be continuously developed by teachers and those who want to pursue the teaching profession. Preservice teachers should develop and enhance their TPACK to equip them with the knowledge and skills they will use in the field or academia. Nonetheless, studies have indicated that new teachers do not believe they can utilize ICT in the classroom. TPACK is a guideline for teachers to balance content and pedagogy as they implement technology into the learning process. Technology integration is not about tools but an agent of change in how things are presented and learned (Cadiz et al., 2024). It will help teachers use other methods instead of traditional techniques and offer each learner customized lessons with instant feedback. Teachers must build technological knowledge to use sophisticated tools like artificial intelligence effectively, pedagogical knowledge to apply these tools to varied learning contexts, and content knowledge to ensure instructional alignment (Azaz et al., 2024). Technology in science education could allow students to simulate experiments in virtual laboratories, but the teacher must equip and guide learners in linking these simulations to real-world scientific principles. TPCK framework represents a paradigm shift in education, contributing to innovative teaching approaches and empowering teachers and students (O'Connor & Natividad, 2023). As technology evolves, TPACK provides a robust foundation for educators to harness AI effectively while maintaining educational integrity (Bibi et al., 2024).

Incorporating new technologies, especially artificial intelligence, in teaching practices has repercussions for improving and developing the teacher's TPACK. Technology advancements in education, like generative AI or GenAI, present good opportunities for educators to expand their teaching approaches. For instance, GenAI provides an opportunity to design meaningful and engaging instructional experiences, encourages individual and diverse learning methods based on the approaches of the study buddy or a teacher, and helps in test designing and feedback (Nelson et al., 2024). Furthermore, AI-based applications created with OpenAI offer input and guidance to the teacher-learner system, increasing the learning process (Perry, 2023). The extension of the TPACK framework towards AI learning indicates that the integration of AI technologies into the practices of a teacher requires competencies that a teacher accrues to manage AI effectively (Murtaza et al., 2024). It has been established that many teachers' knowledge of the use of technology is a key determinant of AI-TPACK, and thus, institutions should develop training programs that focus on closing those gaps. Additionally, data show that the participants in the study who had taught AI beforehand report higher levels of TPACK; it can be concluded that practical work on AI contributes to increasing the readiness and ability of educators to incorporate technologies effectively into learning processes (Zhao et al., 2024). However, adopting AI in education also has drawbacks, including ethical issues and dependency on technology. Teachers must be ready to face such concerns for the technology to work as a reinforcement for conventional approaches to learning. Finally, adopting AI in learning environments can contribute positively to teachers' TPACK development as long as several pre- and post-implementation conditions are practical and widely enforced, including adequate professional development and guidelines for the appropriate use of innovative technologies.

The insufficient TPACK among teachers and the educational shift brought about by implementing the K to 12 curriculum have created a lot of instructional challenges for teachers. In their analysis, Vizconde (2015) emphasized the following new problems with the K to 12 systems: the loss of tertiary-level teachers, the absence of knowledge of implementation guidelines, the two-year shortage of university students, and the lack of implementation resources. Furthermore, Ednave et al. (2018) found that the following difficulties were encountered throughout the K to 12 program's implementation: professional growth and inadequate planning, an increased student study load, and the application of subjects into actual circumstances.

The application of TPACK in science education, particularly in Southeast Asia, has significantly improved instructional practices and addressed specific educational challenges in the region. Kyi and colleagues (2023) conducted a comparative study on preservice science teacher education in Myanmar, the Philippines, and Japan, utilizing the TPACK framework. Their research findings indicated that Myanmar's educational policies focused on content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK). In contrast, the Philippines and Japan integrated and applied technological knowledge (TK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) into their frameworks. All three countries demonstrate insufficient provision of comprehensive TPACK, emphasizing the need for a balanced integration of technological components in teacher education programs to address the requirements of contemporary classrooms. Meanwhile, Mercado et al. (2019) evaluated the significance of the TPACK framework for preservice science teachers at St. Bridget College in Batangas City, Philippines. The findings indicated that the TPACK framework enhances understanding of content, promotes experiential learning, and strengthens the teachers' instructional capabilities. Also, the study highlighted that technology integration enhanced students' interest and motivation, facilitated access to current information, and supported the analysis of graphical data representations. The result highlights the efficacy of TPACK in enhancing the science teaching-learning process and indicates the need to develop technological enhancement activities to provide additional support for teachers. Further, Sarmiento et al. (2019) recommended incorporating TPACK into teacher education curricula to equip educators for the changing educational environment, highlighting that a comprehensive understanding of TPACK allows teachers to develop engaging and compelling learning experiences.

This study enriches TPACK research by addressing the interplay between teacher knowledge, instructional challenges, and demographic factors within a specific educational context. Its hands-on emphasis on laboratory preparation, assessments, and resource constraints deepens our understanding of how TPACK can be effectively utilized to enhance science education. Unlike broader TPACK studies, this research focuses on a specific group of educators—junior high school science teachers in Cabanatuan City, Philippines. By examining a localized context, the study provides a nuanced understanding of challenges and opportunities unique to the region, which can inform targeted interventions for similar settings. This study goes beyond most TPACK research that evaluates knowledge levels by connecting TPACK profiles to particular instructional problems (such as a lack of infrastructure, training, and resources). This integrated perspective highlights how gaps and deficiencies in TPACK domains translate into real-world difficulties in teaching, making the findings more actionable. The study highlights specific classroom challenges, such as insufficient preparation for laboratory activities and student assessment difficulties—issues often underexplored in general TPACK research. Generally, this study determined the technological, pedagogical, and content knowledge, and instructional challenges of junior high school science teachers in the Division of Cabanatuan City. Specifically, this study aimed to assess the respondents' TPACK in Science, describe the instructional challenges junior high school science teachers encounter, and determine if there is a significant relationship between their profile, TPACK, and the instructional difficulties they encounter.

Methodology

Research Design and Sample

This study utilized a descriptive-correlational research design. Sousa and colleagues (2007) described this design as one that "describes the variables and the relationships that occur naturally between and among them." This is the best-suited research design for the study, as the researchers used it to describe the respondents' TPACK and instructional challenges. Meanwhile, correlational research was utilized to determine the significant relationship between these variables.

The respondents of this study were 35 science teachers (Table 1) in the different junior high schools in the Division of Cabanatuan City. They were chosen because they are deemed diverse and included in one of the most significant school divisions in Nueva Ecija. Simple random sampling was utilized for this study. Simple random sampling is the method of randomly selecting a portion of a population (Thomas, 2022). With this sampling procedure, there is an equal chance for every member of the population to be selected. This approach is the most straightforward probability sampling strategy, requiring a single random selection and very little sophisticated demographic data.

Table 1. Profile of the respondents.

Profile	Category	Frequency	Percentage
Age	21 – 30	7	20
	31 – 40	13	37
	41 – 50	9	26
	51 – 60	5	14
	61 and above	1	3
Sex	Male	14	40
	Female	21	60

Profile	Category	Frequency	Percentage
Length of Service	1 – 5	7	20
	6 – 10	12	34
	11 – 15	9	26
	16 – 20	4	11
	21 and above	3	9
School Size	Large	25	71
	Very Large	10	29
Specialization	Biology	7	20
	Chemistry	9	26
	Physics	9	26
	General Science	10	29

Data Collection and Instruments

The researcher first wrote to the School Division of Cabanatuan superintendent to request permission to administer the instruments among the respondents. Following approval, the researcher wrote letters to the teacher respondents' school principals seeking authorization to collect data from their schools and providing them with informed consent forms. The researcher opted to collect the respondents' answers using Google Forms. In this way, respondents had time to review and use the research instrument in their free time. The researchers provided the teacher-respondents with the link to the Google Form after the researchers got permission from the school heads of the participating schools. All information gathered was confidential and would only be used for this academic study.

The study selected Google Forms for data collection since it is simple to use, readily available, and flexible. This choice enhances the response rate and data quality issues, leading to the accomplishment of the research objectives. Teachers, often pressed for time due to their professional responsibilities, appreciated the flexibility of completing the survey online. Moreover, responding anonymously likely reduced hesitancy and encouraged candid participation. In addition, the option of responding to the survey anonymously minimized the possibility of returning to the study with little or no input. Finally, Google Forms has customization features, which help enhance the quality of the data collected when the organization uses them. It became easy to automate the timestamps and have well-structured data exporting that makes the dataset much more accurate.

The study utilized a questionnaire to collect the quantitative data needed for this study. To evaluate the TPACK of the teacher respondents, the researchers used the questionnaire adopted from Gonzales (2018). This questionnaire was validated by four experts in the field and subjected to a dry run at selected schools. Also, the questionnaire was found to be reliable using Cronbach's alpha. Further, the researchers also utilized a questionnaire adopted from Chikwenze and Chukwuneke (2012) to ascertain the instructional problems faced by the teacher respondents. This part of the questionnaire underwent expert- and face-validation. The teacher respondents' TPACK and instructional obstacles were described using frequency count and weighted average, respectively. The significant relationship between the teacher respondents' profile and their TPACK, their profile and the instructional challenges they face, and their TPACK and the instructional challenges they face was ascertained using Pearson r.

To reduce the incidences of self-reported data, the researchers adopted measures that included the following. Respondents may also give answers in their best image (social desirability factor) or respond to the assumption of the researchers instead of reporting facts, which distorts the results. To avoid this, the survey was developed to guarantee the participants' anonymity and ensure that their responses cannot be traced back to them in any way. Also, the findings indicated that teachers' self-estimations about their developed TPACK competencies and instructional difficulties may not reflect authentic assessments. They might be overconfident or underestimate their skills, which could skew the results. To avoid this, the researchers incorporated cross-validation features.

In addition, respondents may not understand the survey items in the same way, which may present several inconsistencies in the set data. To avoid this, the researchers pilot-tested the questionnaire to a small sample of teachers to check for clarity and relevance to the study. Pilot study feedback was incorporated into the instrument to enhance its soundness and ease of understanding. There is a possibility that the data collected are solely based on self-reports gathered from 35 teachers in Cabanatuan City. To overcome this, the researchers ensured that the respondents were selected from different schools to increase the variability of the experiences and environment that the respondents were experiencing.

Ethical Consideration

The researchers informed the respondents and asked for permission to answer the survey. The purpose of taking the survey was also explained to them and why they were chosen to be part of the study. All the data and information gathered were presented with complete transparency and honesty. All the information about the respondents was kept between the respondents and the researchers only. Their respondents' numbers represented them throughout the study, and no information that will be directly connected to their identities or names was made.

Results and Discussion

Assessment of the Respondent's TPACK

Table 2 shows the TPACK of respondents' terms regarding technological knowledge. From the given data, 93.3% (33/35) answered that they are satisfactory and outstanding in using a projector and laptop in the class. Regarding solving simple technical glitches, 93.3% (33/35) are satisfactory and outstanding. 81.85% (29/35) are satisfactory and above using animation and videos to support the lesson. 80% (28/35) are satisfactory and above in reaching their students using online messaging apps. In comparison, 74.3% (26/35) are satisfactory. The above is in Statement 5 (creating group accounts intended for sharing files and other learning materials relevant to the topics in science). 81.85% (29/35) are satisfied and above in using multimedia platforms like Facebook and YouTube in some of their activities and using jargon words in technology during their discussions. 100% (35/35) are satisfactory and above in giving activities involving technology and using laboratory equipment with technology, while 97.1% (34/35) are satisfactory and above in applying specific techniques when using laboratory equipment. It can be noted that among the statements, teachers rated the use of video and animations to support the lesson overall as outstanding.

Regarding technological knowledge, the overall weighted average of the teachers is 3.52, which means they are delighted with this factor. Different literatures support the findings of the study. Gonzales (2018) discovered that rating groups differed in the degree of technical expertise used by biology teachers. Both teachers and students exhibit a similar pattern, which indicates intermediate proficiency. Helppolainen and Aksela's (2020) findings indicated that chemistry teachers' ICT knowledge, abilities, beliefs, and usage were similar to those of other scientific teachers. Nonetheless, there were a few minor differences within the teachers' groups, which may have resulted from the nature of chemistry and the technical, pedagogical, and subject-matter expertise required for the classroom teaching-learning process. According to the interpretation of Jang and Tsai's (2013) findings, science teachers in secondary schools were more confident in their pedagogical and content knowledge but less confident in their technological expertise and how it related to those two areas, which is consistent in the study.

Moreover, in terms of the pedagogical knowledge of the respondents, 100% (35/35) are satisfactory and above in terms of using a variety of strategies in presenting topics in science, assessing students' performance in the classroom, demonstrating fairness in dealing with students, trying another strategy in teaching if the students are having difficulty understanding the lesson, adapting a teaching style based on the understanding of their students, adjusting the teaching method when some of the students are having difficulty in understanding the lesson and managing and organizing the classroom. 97.1% (34/35) are satisfactory and above in providing activities that can help students cope with the subject and are knowledgeable in the pacing of the lessons appropriate to the student's needs and difficulties. The overall weighted average for pedagogical knowledge is 4.01, meaning the teachers are delighted with this factor. Similarly, Gonzales (2018) observed that the assessment of biology teachers' pedagogical knowledge is consistent across all indicators, indicating that they all concur that certain aspects of using appropriate biology teaching methodologies still need to be addressed to attain the highest level of proficiency. Guzey and Roehrig (2009) also discovered that teachers' motivations for choosing classroom teaching-learning strategies were strongly tied to their ideas about science, successful teaching methods, the goals of teaching science, and student comprehension.

Lastly, when it comes to their content knowledge, 100% (35/35) said that they are satisfactory and above when it comes to discussing the science lessons, encouraging students to ask questions, relating science topics to other subject areas, showing confidence in delivering the lessons, discussing lessons with less relying on the book, providing updates related to the topic, giving simple yet innovative laboratory activities, and using traditional assessment techniques in teaching science lessons. 97.1% (34/35) are satisfactory and above in setting objectives within the students' capabilities. In comparison, 93.3% (33/35) are adequate and above in explaining complex concepts effortlessly so that the students can quickly grasp them. The overall weighted average for content knowledge is 3.88, which means the teachers are delighted with this factor. However, Gonzales (2018) found that even students recognize that their biology teachers lack general knowledge based on the indicators. Their assessment is reinforced by the opinions of class observers who are more knowledgeable about the subject.

Table 2. Descriptive analysis of the respondents' TPACK.

Knowledge	O 5	VS 4	S 3	FS 2	P 1	Weighted Mean	Verbal Description
Technological Knowledge						**4.01**	**Very Satisfactory**
1. I use a projector and laptop in the class.	15 (42.9)	11 (31.4)	6 (17.1)	3 (8.6)	0 (0)	4.09	Very Satisfactory
2. I know how to solve simple technical glitches.	16 (45.7)	9 (25.7)	8 (22.9)	2 (5.7)	0 (0)	4.11	Very Satisfactory
3. use downloaded animations and videos to support our lesson.	18 (51.4)	7 (20.0)	10 (28.6)	0 (0)	0 (0)	4.23	Outstanding
4. I contact my students regarding our lesson through online messaging.	17 (48.6)	5 (14.2)	10 (28.6)	3 (5.6)	0 (0)	4.03	Very Satisfactory
5. I created an online group account for our class to share files and learning materials relevant to our topics in science.	18 (51.4)	7 (20.0)	5 (14.3)	5 (14.3)	0 (0)	4.09	Very Satisfactory
6. I include multimedia platforms like Facebook and YouTube in some of our activities.	14 (40.0)	8 (22.8)	10 (28.6)	3 (5.6)	0 (0)	3.94	Very Satisfactory
7. I mentioned jargon during classes, which is somewhat "techie" in nature.	16 (45.7)	5 (14.3)	13 (37.1)	1 (2.9)	0 (0)	4.03	Very Satisfactory
8. I give activities that involve the use of technology.	15 (42.9)	8 (22.85)	4 (11.4)	8 (22.85)	0 (0)	3.86	Very Satisfactory
9. I make use of laboratory equipment with ease.	14 (40.0)	10 (28.6)	8 (22.8)	2 (5.7)	1 (2.9)	3.97	Very Satisfactory
10. I apply specific techniques when using laboratory instruments.	13 (37.1)	8 (22.85)	8 (22.85)	5 (14.3)	1 (2.9)	3.77	Very Satisfactory
Pedagogical Knowledge						**4.01**	**Very Satisfactory**
1. I use a variety of strategies in presenting topics in science.	15 (42.9)	11 (31.4)	6 (17.1)	3 (8.6)	0 (0)	4.09	Very Satisfactory
2. I know how to assess students' performance in the classroom.	16 (45.7)	9 (25.7)	8 (22.9)	2 (5.7)	0 (0)	4.11	Very Satisfactory
3. I show fairness in dealing with students.	18 (51.4)	7 (20.0)	10 (28.6)	0 (0)	0 (0)	4.23	Outstanding
4. I try another strategy when my students struggle to understand the lesson.	17 (48.6)	5 (14.2)	10 (28.6)	3 (5.6)	0 (0)	4.03	Very Satisfactory
5. I correct students' misconceptions about specific topics.	18 (51.4)	7 (20.0)	5 (14.3)	5 (14.3)	0 (0)	4.09	Very Satisfactory
6. I adapt my teaching style based on the level of understanding of my students.	14 (40.0)	8 (22.8)	10 (28.6)	3 (5.6)	0 (0)	3.94	Very Satisfactory
7. I adjust the teaching method when some students struggle to understand the lesson.	16 (45.7)	5 (14.3)	13 (37.1)	1 (2.9)	0 (0)	4.03	Very Satisfactory
8. I know how to manage and organize our classroom.	15 (42.9)	8 (22.85)	4 (11.4)	8 (22.85)	0 (0)	3.86	Very Satisfactory
9. I provide activities that can help students cope with the subject.	14 (40.0)	10 (28.6)	8 (22.8)	2 (5.7)	1 (2.9)	3.97	Very Satisfactory
10. I know the pace of lessons appropriate to the needs and difficulties of my students.	13 (37.1)	8 (22.85)	8 (22.85)	5 (14.3)	1 (2.9)	3.77	Very Satisfactory
Content Knowledge						**3.88**	**Very Satisfactory**
1. I discuss science lessons.	13 (37.15)	16 (45.7)	6 (17.15)	0 (0)	0 (0)	4.20	Very Satisfactory
2. I encourage my students to ask practical questions.	15 (42.9)	11 (31.4)	7 (20.0)	2 (5.7)	0 (0)	4.11	Very Satisfactory
3. I relate science topics to other subject areas.	11 (31.42)	12 (34.3)	8 (22.85)	4 (11.43)	0 (0)	3.86	Very Satisfactory
4. I set lesson objectives within the experiences and capabilities of my students.	13 (37.1)	10 (28.6)	9 (25.7)	2 (5.7)	1 (2.9)	3.91	Very Satisfactory
5. I show confidence in delivering the lesson.	14 (40.0)	11 (31.4)	8 (22.9)	2 (5.7)	0 (0)	4.06	Very Satisfactory
6. I can discuss lessons in my language and not rely much on the book.	12 (34.3)	14 (40.0)	6 (17.1)	3 (8.6)	0 (0)	4.00	Very Satisfactory
7. I provide updates related to our topic.	11 (31.4)	11 (31.4)	10 (28.6)	3 (8.6)	0 (0)	3.86	Very Satisfactory
8. I give simple yet innovative laboratory activities.	6 (17.2)	12 (34.3)	13 (37.1)	4 (11.4)	0 (0)	3.57	Very Satisfactory
9. I use non-traditional authentic assessment techniques like concept mapping, debates, and practical exams.	8 (22.8)	10 (28.6)	10 (28.6)	7 (20.0)	0 (0)	3.54	Very Satisfactory
10. I explain complex topics as if they were easy; thus, my students understand them better.	12 (34.3)	7 (20.0)	11 (31.4)	3 (8.6)	2 (5.7)	3.69	Very Satisfactory

The varying scores in the TPACK components, including technological content knowledge (TK), pedagogical content knowledge (PK), and content knowledge (CK), indicate factors like professional experience, available resources, professional development, and system support. In the present study, technological and content knowledge (TK and CK) results were very satisfactory and outstanding in one pedagogical knowledge (PK) domain, identifying the strengths and limitations of the teacher's professional practice.

The relatively more substantial scores in TK might be associated with the enhanced availability of Information Communications Technology–ICT gadgets and the incorporation of technology in learning after the onset of the COVID-19 pandemic. It is expected that teachers have developed some level of mastery in elements such as online classrooms, learning platforms, video-conferencing applications, and related tools due to experiences in remote schooling (Zhao et al., 2024). Further, many professional development programs focus on skills development for basic technology applications, resulting in higher TK levels. However, such a high level of TK might indicate the possession of not integrated technological knowledge but only essential technological competencies, although integration is an advanced form of combining TK with CK and PK (Chai et al., 2024).

From the above result, where CK has a very satisfactory mean, a perception can be gained that the teachers have sufficient knowledge and expertise in their respective fields. This is expected, for content knowledge must be certified and practiced as a science teacher. The stability and measurability of CK are partly attributable to the degree programs and continuous learning that underpin this strength (Shulman, 1986). However, deciding on a set of CK alone is insufficient to foster good quality teaching because content knowledge is needed with instructional and technological practices (Mishra & Koehler, 2006).

PK has achieved a very satisfactory level, which shows that teachers are very aware of instructional practices, classroom management, and student management practices. Many science teachers in the locality, especially in the region requiring additional support, have undergone rigorous teacher training programs focused on teaching and learning (UNESCO, 2022). Furthermore, the experience that respondents had in teaching – most of them had 6–10 years –could explain good knowledge of pedagogical approaches and a more extended practice, which refines those skills. Nevertheless, a corollary of such an endeavor is that PK's methods may not necessarily carry over into settings characterized by higher technological affordance, where teachers are expected to employ varied strategies that ensure the high utility of tools.

While each TPACK facet received a high rating, integrating these facets, specifically Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPACK), maybe a problem. For example, teachers pointed out that they are challenged to create activities integrating technology and learning context and knowledge appropriately (Chai et al., 2024). Standardization and automation of services; limited access to basic infrastructures; inadequate preservice and in-service training; and lack of sustained support to foster the enhancement of the physical, social, learning, health/safety, virtual, and cultural-human dimensions prevent them from doing so as designed and expected (Zhao et al., 2024).

Instructional Challenges

Table 3 shows the instructional challenges of the teachers. 82.85% (29/35) agreed that their school has an unavailability of science equipment for typical work. 60% (21/35) agreed that their classroom is overcrowded and that there are inadequate instructional materials in their school. In comparison, 65.7% (23/35) agreed that there is a lack of adequate infrastructure for both students and teachers, while 20% (7/35) agreed that their school has an ill-equipped laboratory. 54.3% (19/35) agreed they have insufficient capacity building, training, and skills enhancement. In comparison, 8.6% (3/35) agreed that they have poor mastery of teaching science content and have inadequate knowledge of using the science material equipment, and 17.1% (6/35) agreed that their understanding of the method of science instruction is limited. 28.6% (10/35) agreed that the time allocated for teaching science subjects is inadequate. The overall weight for instructional challenges is 2.86, meaning that teachers are neutral regarding their instructional difficulties. Implementing the K-12 curriculum has raised community concerns about the Philippine government's preparedness for changes, including the country's poverty, technology accessibility, teacher preparation, and even the low pay of the academic workforce.

Table 3. Descriptive analysis of the instructional challenges of the respondents.

Indicators	SA	A	N	D	SD	Weighted Mean	Verbal Description
Science equipment is unavailable for typical work	5 (14.3)	16 (45.7)	8 (22.8)	6 (17.1)	0 (0)	3.57	Agree
The classroom is overcrowded in our school	3 (8.6)	14 (40.0)	4 (11.4)	12 (34.3)	2 (5.7)	3.11	Neutral

Indicators	SA	A	N	D	SD	Weighted Mean	Verbal Description
There is a lack of adequate infrastructure for both students and teachers.	6 (17.1)	10 (28.6)	7 (20.0)	9 (25.7)	3 (8.6)	3.20	Neutral
In teaching science, instructional materials are inadequate in our school.	8 (22.8)	8 (22.8)	5 (14.3)	12 (34.3)	2 (5.7)	3.23	Neutral
There is no capacity building, training, and skills enhancement	3 (8.6)	10 (28.6)	6 (17.1)	12 (34.3)	4 (11.4)	2.89	Neutral
I have poor mastery of teaching content	2 (5.7)	1 (2.9)	9 (25.7)	13 (37.1)	10 (28.6)	2.20	Disagree
I have poor knowledge of using the science materials and equipment	2 (5.7)	1 (2.9)	9 (25.7)	17 (48.6)	6 (17.1)	2.31	Disagree
The time allocated for teaching science subjects is inadequate.	2 (5.7)	8 (22.9)	5 (14.3)	18 (51.4)	2 (5.7)	2.71	Neutral
My knowledge of methods of instruction for science is limited	4 (11.4)	2 (5.7)	12 (34.3)	14 (40.0)	3 (8.6)	2.71	Neutral
Our school has an ill-equipped laboratory	3 (8.6)	4 (11.4)	9 (25.7)	15 (42.9)	4 (11.4)	2.63	Neutral
Weighted Mean						**2.86**	**Neutral**

Significant Relationship Between the Profile of the Respondents, their TPACK, and their Instructional Challenges

Regarding the relationship between the respondents' profile and their TPACK, the age of the respondents has a significant relationship (negative correlation) with their technological knowledge (Table 4). Years of experience teaching the respondents are also significantly related (negative correlation) to their technological knowledge. This means that their technological knowledge decreases as the respondents' age and years of teaching experience increase. Moreover, the overall TPACK of the respondents is significantly related to their age and years of teaching experience. However, the significant relationship between the overall TPACK and years of teaching experience is negligible. This study demonstrates that demographic factors, including age and teaching experience, are essential in determining teachers' TPACK and how educators incorporate technology into instruction. These patterns identify the advantages and disadvantages of a particular teacher demographic, helping professional development designers identify the model that fits them.

Age is a causative factor in relating differences in technological knowledge (TK) and incorporation of the same in the system. Teachers below forty years old show higher TK because of enhanced access to technological resources during training and technology usage (Koh et al., 2023). This digital familiarity makes them more comfortable experimenting with new education technologies and more flexible to innovations. On the other hand, the results showed that older teachers may possess higher PK and CK because of their years of teaching experience. However, they often have difficulties updating their technological competence, which results in a comparatively lower average TPACK score if no specific training is provided (Zhao et al., 2024).

Table 4. Correlational analysis between the profile of the respondents, their TPACK, and instructional challenges.

	Technological Knowledge	Pedagogical Knowledge	Content Knowledge	Overall TPACK	Instructional Challenges
Age	-.670**	.013	-.222	-.392*	-.559**
Sex	.195	.302	.145	.257	-.236
Years of Experience	-.609**	.074	-.183	-.327	-.441**
School Size	-.027	-.174	-.197	-.144	.062
Specialization	-.113	.155	-.026	-.004	-.234
Instructional Challenges	.396*	.207	.350*	.386*	

**Significant at 0.05, ** Significant at 0.01*

CK and PK scores are also affected by the years of teaching because experienced teachers have a deeper perspective of the content of the curriculum and the right approach to helping the learners grasp that knowledge. The data shows that teachers with 6 to 15 years of experience have nearly equal mean scores in both CK and PK because of the improvement of their teaching methods and the education system's development needs (Chai et al., 2024). Experience, which is broader than 20 years, may affect the skills in TPACK integration, especially in combining TK with PK and CK, because participants use traditional approaches. These problems must be supplemented by professional development programs for experienced teachers to integrate technology into their daily practice.

Both age and teaching experience have a significant relationship – and in most cases, these two variables are inseparable since they are TPACK's significant predictors. For instance, mid-career teachers, typically aged 31–40, often achieve the highest TPACK scores due to their balance of professional maturity and adaptability to new technologies (Lin et al., 2023). On the other hand, early-career teachers may best teach TK lessons but will still need to boost their CK and PK. In this case, for the late-career educators, their rich CK and PK can facilitate the process of TPACK development if they are provided sufficiently with technological training.

The disparity in access to professional development and support governs demographic patterns of TPACK in the Southeast Asian region. The younger teachers did better than their older colleagues, especially in urban schools. They have easy access to technological tools and training compared to schools in rural areas, where the infrastructure can hamper continuous and effective teaching and learning processes (UNESCO, 2022). Based on Kumala et al. (2022), the TPACK profile of science instructors was based on demographic characteristics, and male teachers scored better on the TPACK scale than female teachers. The results for the age group indicated that instructors under 30 and those between 30 and 40 had superior technology abilities compared to older teachers. Civil servant teachers scored somewhat higher on employment status than non-civil servant teachers. Regarding the teaching experience, the length of the teacher's teaching career is directly correlated with their TPACK. The findings showed a correlation between teachers' TPACK and demographic characteristics.

Moreover, in terms of the relationship between the profile of the respondents and their instructional challenges. The data shows that the respondents' age and year of experience are significantly related (negative correlation) to their instructional difficulties. This means that as the age and years of experience increase, the instructional challenges they encounter decrease. According to Koh and Chai's (2011) study results, the degree of training of teachers affects their ability to collaborate with other professionals, use classroom supplies and equipment, and employ instructional tactics. More specialized or customized teaching methods were used in the classroom by teachers who had training in inclusive or special needs education than those who did not (Jardinez & Natividad, 2023; Santos & Natividad, 2023). Additionally, it was shown that teachers' cooperation with other experts was influenced by their years of teaching experience. Compared to teachers with bachelor's degrees, those with MA/MSc and PhD degrees were shown to have less difficulty detecting students' needs and modifying their lesson plans and instructional resources. The study concluded that the discovered demographic characteristics influenced at least one of the teachers' instructional approaches and teaching issues.

Lastly, in terms of the relationship between the respondents' TPACK and their instructional challenges, It is shown in the table that technological knowledge and content knowledge are significantly related (positive correlation) to instructional challenges. This means that as the technological and content knowledge of the respondents increases, the instructional challenges they encounter also increase. Further, the overall TPACK is significantly related (positive correlation) to instructional difficulties, which means that as the TPACK of the respondents increases, their instructional challenges also increase. Similarly, Patahuddin et al. (2016) suggested that the qualitative examination of the four intersected TPACK constructs assists in understanding teachers' challenges and opportunities when using exploratory-based technology. According to the PCK study, experienced instructors often exhibit more material and pedagogical knowledge since their real teaching experience can produce more content and pedagogical expertise the more years they have been in the classroom (Jang & Tsai, 2013). Friedrichsen et al. (2009) claimed that compared to new teachers who are still honing their integrative skills and knowledge, experienced teachers typically possess a superior understanding of integrating content and pedagogy because they have had more opportunities to gain this knowledge through their teaching experiences.

For the instructional issues revealed in this study on TPACK and instructional practices, applying related approaches can enhance the teaching quality and the learners' achievement. All these strategies relate to staff development, budget priorities, and facility upgrades. Targeted Training Programs such as Customized TPACK Workshops could help fill the identified gap, such as using technology in science teaching and learning or designing appealing multimedia lessons. For example, such activities as workshops can help teachers learn how to apply simulation and other interactive instruments to explain certain concepts from science.

AI and EdTech Literacy training could improve the way instruction is delivered. For instance, artificial intelligent tools such as intelligent tutoring systems can help customize student learning and assist teacher's performance analysis. Collaborative Professional Learning Communities can also assist the teachers in knowing what works best, planning jointly and mutually discussing and solving the implementation issues of the lessons. By implementing such examples of solution-oriented approaches, schools and educational authorities can manage instructional concerns systematically to improve teacher preparedness to deliver quality technology-enhanced education. Therefore, these strategies' ongoing assessments and refinements will be essential to sustaining them in the long run.

The findings from this study have broader implications for other divisions and regions in the Philippines, offering insights into systemic challenges and opportunities for improvement in education nationwide. The variability in TPACK competencies shows how teachers' preparedness differs across regions and between urban and rural areas. Urban school environments provide them with better access to resources and training. Conversely, rural schools and teachers are constrained by low technological advancement and limited or fewer opportunities to attend professional development sessions (UNESCO, 2022). Reducing these gaps calls for the impartial distribution of resources and remarkable investment in needy schools. The research findings highlight the vector of continuing teacher education focusing on technology, teaching, and content knowledge. Similar gaps may exist in the other divisions, and therefore, national-level policies should require routine specific training as provided by the DepEd's ICT competencies. These initiatives can ensure that teachers nationwide are equipped to handle the demands of 21st-century education.

The above challenges, like infrequent supplies and poor quality of learning materials, poor infrastructure, and lack of finances of schools, are some of the systemic problems experienced in most schools within the Philippines. The findings demand improving the country's school infrastructure, including internet connectivity, well-equipped laboratories, and access to technology. These shortcomings can be easily overcome by cooperating with non-governmental organizations, governmental funding programs, and public-private partnerships. The focus of TPACK on technological knowledge betrays the possibilities of using digital learning in teaching science. For instance, other divisions can emulate the implementation of virtual laboratory and AI platforms to deal with constraints such as a shortage of laboratory facilities in teaching science subjects and further enhance students' understanding of concepts.

In addition, the study emphasized the need to provide cross-divisional benchmarking of best practices and resources. For example, divisions that developed a high level of TPCK can become a center of running workshops and providing experiences for less developed divisions. A combination of the recommended regional offices and programs can help bring about a culture of sustained improvement. Thus, the rest of the divisions in the Philippines may use such insights and follow a strategic and systematic approach to manage the issues associated with the teachers to achieve more fair and efficient educational outcomes all over the country.

Conclusion and Recommendations

Conclusion

Most of the science teachers in the division of Cabanatuan City, specifically those who belong in the identified public junior high schools, belong to those groups of teachers who have been teaching for more than five years. They also teach in schools that are identified as significant and extensive school categories. The respondents' technological, pedagogical, and content knowledge can be evaluated as above average, meaning they have a strong foundation of skills and expertise in technology, pedagogy, and science content. Even if the TPACK profile of the respondents is above average, they still encounter instructional challenges, such as the unavailability of materials, equipment, and infrastructure to be used in teaching science, which may affect their knowledge, skills, and attitudes toward teaching. Other instructional challenges the respondents encounter include developing consistent procedures and activities that effectively engage students. However, science teachers address these challenges by executing changes in their lesson plans, seeking student feedback, and developing alternative materials. Age is the number one factor that significantly influences the development of technological knowledge among science teachers. It also relates to the instructional challenges they encounter, which means that as science teachers get older, they experience more. Furthermore, instructional challenges influence science teachers in the division, particularly regarding their technological and content knowledge. A call for further research, such as longitudinal studies on TPACK development programs' long-term impact, is warranted.

While the study provides valuable insights, it is essential to acknowledge certain limitations that may affect the generalizability and depth of its findings. Primary limitations include the small sample size and the exclusive reliance on quantitative data. The data collection was limited to 35 participants from seven recognized public junior high schools in Cabanatuan City. Nevertheless, generalizing the results of this study to other populations may be limited since the sample might only offer a view of the TPACK profiles and instructional difficulties in the local setting. A larger sample size would have provided statistically rigorous approaches to the study. It would also have provided for diverse teachers' experiences, especially concerning the school type, socioeconomic status, and personal teaching style. This also means that the sample size is limited, and, therefore, the observed effects could be skewed by extreme values, increasing the chances of fused findings.

In addition, this study was mainly dependent on quantitative data obtained from closed-ended survey questionnaires, which might not provide the detailed information needed to examine teachers' TPACK proficiencies and teaching difficulties. Qualitative measures seldom give an insight into why specific teachers, teaching in particular contexts, teach in a manner that is analyzed and quantified from a sample. For example, the survey may reveal the teachers' technological knowledge is very satisfactory. Still, it fails to show how teachers use this knowledge in practice or what constraints they encounter. The study might have used other sub-techniques, such as interviews, focus group discussions, or class observation, which can offer more comprehensive information on what teachers thought and did. Such mixed-methods approaches would enable researchers to crosscheck some of the gathered data and paint a broader picture of the hurdles and benefits of developing TPACK. The study contributes to TPACK and instructional difficulties when teaching science. Despite their strengths, further research on the study's limitations may strengthen the solidity and generalization of the findings. Increasing the sample, using both a qualitative approach and longitudinal design, may offer a richer understanding and assist in formulating better development plans for teachers and improving education.

Recommendations

For a more comprehensive understanding of this study, other demographic factors of the respondents, such as the professional qualifications (such as educational attainment and the number of relevant training), should be included. To improve the TPACK profile of the respondents, the division of Cabanatuan City can develop a series of training sessions to meet the needs of their science teachers in terms of knowledge and skills in technology for education, pedagogy, and science content. Furthermore, the division could conduct a quality and quantity check of the science infrastructure and equipment in each school to see the needs of the schools, specifically in terms of learning materials such as laboratory apparatuses and laboratories, so that learning in science will not only be limited to books and modules. Also, science teachers should allot time attending trainings and workshops about properly handling and using laboratory equipment and apparatuses for teaching and learning in science. The division of Cabanatuan City should provide training to the seasoned science teachers in its locality about the recent development of the knowledge and concepts in science and the proper utilization and integration of technology in teaching science among the students so that seasoned teachers will not be left behind by those newly hired teachers who were knowledgeable in these areas.

Most studies found a significant correlation between teaching experience, age, and TPACK competencies, which means that training programs should be designed based on teachers' needs. For instance, some of the teachers may require some guidance on what they are supposed to teach and how they are supposed to teach it, an aspect that is perhaps easier taught to young teachers; on the other hand, there may be teachers whose primary need is on how to incorporate technology in their teaching. Thus, divisions across the country can use this differentiated approach to leverage the effectiveness of the professional development programs. The results presented in this paper can help policymakers improve national education policy agendas. For instance, DepEd can provide units, courses, or lessons that bear TPACK focus in preservice teacher education training to guarantee that the teachers who first enter the service are equipped with symmetrical dispositions. Furthermore, the details on the policies of lifelong learning for the in-service teachers would also enable them to do the necessary up-skilling for the practice.

This study recommends training initiatives and partnerships with educational technology providers since they have a central role in endorsing the teacher professional development to foster excellence in information literacy instruction that incorporates appropriate use of technology. Some are Google for Education Training programs, which prepare educators to train in the use of tools such as Google Classroom, Docs, and Slides. These include basic, intermediate, and enhanced programs, including Google Certified Educator. Teachers learn practical applications, such as creating collaborative assignments, integrating multimedia into lessons, and streamlining assessment processes. Another is Microsoft, which collaborates with schools globally to provide professional learning under the Company's Education Transformation Framework. This includes developing exercises such as training and workshops on Microsoft Teams, OneNote, and other apps to support teamwork and personalized learning. The framework is also helpful for administrators in planning for long-term technology implementations. As usable AI enters the classroom, programs such as Khan Academy's "Khanmigo" expose educators to AI that supports learner differentiation and instructional effectiveness. Professional learning enables teachers to grasp AI possibility and challenge, moral implications, and application.

It takes feedback from time to time in such endeavors because, after product development, educators are better positioned to explain the emerging problems and gaps that need to be reflected in program development to meet market demands. Training indeed involves regular assessment and feedback to meet the needs of educators from time to time. The ongoing feedback means that there will always be a cycle of improvement that will make training relevant, actionable, and practical. Engaging teachers in the evaluation process enhances program effectiveness and empowers educators to take ownership of their professional growth. These initiatives can significantly improve educational technology integration in teaching and learning by prioritizing collaboration and adaptability.

Conflict of Interest

The authors declare no conflict of interest.

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Authorship Details

Sogue (60%): Concept and design, data acquisition and analysis, data interpretation, writing the manuscript. Natividad (40%): writing the manuscript, conceptualization, supervision, editing the manuscript.

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