RESEARCH ARTICLE

Technological, pedagogical, and content knowledge of diploma in professional education graduates teaching biology

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Abstract: Content, pedagogy, and technology knowledge are central to effective teaching. Moreover, the interaction and integration of these knowledge bases challenge teachers, especially non-teacher education graduates including diploma professional education (DPE) graduates. Utilising adapted instruments, this study investigated the teaching competence of biology teachers who are DPE graduates, specifically their Technological, Pedagogical, Content Knowledge (TPACK) and Biology teaching competence to design a teacher professional development (TPD) programme. Most teachers were BS Nursing graduates with professional teaching licenses and teaching experience ranging from 3 to 10 years. Also, most teachers received between one to five TPDs focused on biology, pedagogy, and technology. Among the TPACK components, the teachers perceived that they were least competent in pedagogical knowledge (PK) and pedagogical content knowledge (PCK). Although the teachers agreed on their perceived overall TPACK competence, there is still an avenue to strengthen their TPACK. Teachers also believed that they were least competent in biological cellular processes. Need-based teacher professional development programmes are recommended to enhance Biology teachers' TPACK, and ultimately, biology education.

Keywords: biology; biology education; teacher competence; TPACK

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Introduction

Science education, with biology, chemistry, and physics as major disciplines, plays a significant role in the country's economic development. The essential impacts of science and science education have been incessantly emphasised in the literature. Science education brings technological advancement, promotes national wealth, and improves health and industry. At the micro-level, beneficial outcomes of teaching science include promoting the understanding of what is known and elucidating what is unknown, strengthening the ability to deal with doubt and uncertainties, uncovering evidence, and soundly deriving implications (dela Fuente, 2019). Similarly, biology education constitutes an apparent niche in society today as it comprises environmental education, an essential facet of sustainability. Science, technology, and education are intricately woven and together serve as the backbone of development (Etebu & Amatari, 2020). Biology education covers essential topics such as biodiversity, climate change, health, and welfare, which are vital in planning a sustainable future (Jeronen et al., 2016). Additionally, biology curricula are designed to offer students vital scientific and technological knowledge and skills they need to solve problems and make decisions in everyday life based on scientific attitudes and noble values (Hiong, 2013).

Even before the unprecedented shift to online or flexible learning modes brought about by the restrictions on in-person classes due to the Covid-19 pandemic, the Philippines has seen waves of reforms in the educational system. These adjustments in the educational setup were prompted by global and universal trends and development (Commission on Higher Education, 2011), influencing accommodation and consequent adaptation to the surge of current novelties to produce globally competent individuals. Furthermore, these reforms are driven by the introduction of outcomes-based education, internalisation, and globalisation of education. In the Philippines' educational setup, however, the most recent reform was the implementation of the K-12 curriculum, which resulted in a cascade of changes, including an additional two years of high school and the senior high school programme. Additionally, such reform necessitated significant changes, not just at the high school level but at all education levels, impacting teaching-learning, the curricula, and the Philippines' education system.

Before the implementation of the Enhanced Basic Education Programme in 2016, the Philippines was one of the last three countries in the world that still offered a 10-year basic education curriculum. Grounded on the Republic Act 10533, the programme commonly referred to as the K to 12 programme outlined a plethora of changes in the curriculum, teacher training and education, and transitioned and impacted the higher education sector. One of the most identifiable hallmarks of the K to 12 programme is offering specific tracks and specialised strands in two additional senior high school (SHS) years to provide specialised or advanced education, resulting in a need for specialist teachers. Consequently, training was provided to prepare science teachers already in the system and specialists were hired. Nevertheless, the question of the sufficiency of the training or the pedagogy of a specialist without teaching experience or professional education units arises, therefore, this study sought to identify and consequently address this gap in biology education.

Based on available data, there are fewer enrolees in the institutions that offer specialisation in Biology than in other majors. According to the September 2019 Licensure Examination for Teachers (LET) results, only 54,179 out of 136,523 (39.68%) secondary teachers passed the licensure (Professional Regulation Commission, 2019), suggesting a dearth of licensed secondary teachers, especially those specialised in science education, such as biology. Additionally, in the recent September 2021 LET, only 10,318 of 17,863 (57.76%) successfully passed the licensure examination (Professional Regulatory Commission, 2021). One can become a licensed Biology teacher (LPT) through a Teacher Education programme specialising in Biological Sciences, such as the Bachelor of Secondary Education (BSEd) in Biological Sciences. However, changes were made as the BSEd specialising in biology, chemistry, and physics, such as BSEd Biology, are currently integrated into a more generalised major, BSEd Science, which impacts the pool of teachers specialised in teaching biology.

An alternative way to earn professional education units and consequently be qualified to take the licensure exam and earn a professional teacher license is the Certificate/Diploma in Professional Education (CPE/DPE) programme. The relatively new CPE/DPE programme was offered to allow non-education graduates to earn professional education units to apply for a professional teacher's license. According to the Commission on Higher Education (2017), a non-education graduate may take the board exam after earning 18 units of professional education units (CPE) or after completing an additional 12 units of experiential learning courses (DPE). Integrating content with knowledge of teaching methods and practices is unarguably an ideal concept, such as those graduates of biology or agriculture. However, this is not the same for graduates with bachelor's degrees in health professions. For instance, there are only a few biology courses and subjects essential for biology teaching in the BSc in Nursing. DPE graduates of bachelor's degree programmes in the health profession may find the content and pedagogy challenging. Considering that there are limited studies focused on biology teachers who are non-teacher education graduates, biology teachers who are DPE graduates are therefore the highlight of the study.

Numerous studies have identified factors that impact the quality of teaching-learning including teacher quality. According to Guerriero (2014), teacher quality is represented by several indicators and Shulman (1986) identified that teacher knowledge reflects teacher quality, which he further divided into knowledge bases, among which, Pedagogical Content Knowledge (PCK) is of particular interest. PCK is defined as a remarkable synergy of teaching practice and content distinct to teachers and educators (Mu et al., 2018). As a multidimensional construct, teacher knowledge comprises content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (König et al., 2014) and fuses content knowledge into pedagogy. As mentioned, Biological Science CPE/DPE graduates face the challenge of learning content, pedagogy, and integrating content and teaching.

TPACK signifies a wide-ranging understanding of dynamic and complex interplays between how technology could shape the content and how the application of technology influences teaching and learning, and how to represent and convey specific ideas, topics or content to students (Chien et al., 2012) considering the increased technology use in education.

The restrictions placed because of the COVID-19 pandemic ultimately led to the unprecedented shift to an online, flexible, or modular mode of education. Therefore, DPE graduate biology teachers encountered the challenge of adopting not only content and pedagogy but also technology. Technology (TK), content (CK), and pedagogical knowledge (PK) and the relationships among these components are at the very core of good teaching (Koehler & Mishra, 2008), especially in the 21st century. Teachers'

TPACK (Technological, Pedagogical, and Content Knowledge) refers to the effective integration of technology in teaching (Pamuk et al., 2015).

This study looked into the profile of the DPE graduate biology teachers including whether they are licensed, their teaching experience, and their undergraduate degree, as well as the number of TPDs focused on content, pedagogy, and technology that the teachers received. The TPACK of DPE graduate biology teachers was assessed to identify their strengths and difficulties to provide appropriate and necessary interventions to improve their TPACK and ultimately improve student learning. Odumosu and Areelu (2018) stated that for any country that aspires to progress, students must have teachers who possess considerable content and pedagogical knowledge.

Method

The study respondents were high school DPE graduate biology teachers who were initially graduates of non-teacher education programmes such as healthcare-related degrees (BS Nursing, BS MedTech, and the like) and pure sciences (BS Biology etc.). The TPACK survey instrument developed by Pamuk et al. (2015) was utilized to determine the participants' TPACK level. This instrument comprises seven categories that group a total of 37 items based on the TPACK constructs: three categories for the core knowledge bases (CK, PK, TK), three categories for the second-level knowledge bases (PCK, TCK, TPK), and one category for TPACK. The survey was scored using a four-point agreement scale. Since DPE graduate biology teachers only earned professional education units through the DPE programme, there is a need to investigate their content knowledge, therefore, the teachers' biology content knowledge was evaluated using the Department of Education's (DepEd) Biology Most Essential Learning Competencies (MELCs).

Nonparametric tests were utilized because data normality was not ensured and the sample size was not sufficient and did not satisfy assumptions for parametric tests. To determine the participants' TPACK level concerning their knowledge bases, the weighted mean of the TPACK survey responses was calculated and the overall mean for each knowledge base was also determined to explore the participants' level for each knowledge base. The participants' biology content knowledge was further explored using the DepEd's Content Standards for Biology.

Results and Discussion

Profile of the Biology Teachers

In terms of the Licensure Examination for Teachers (LET) administered by the Professional Regulatory Commission (PRC), most respondents (81.81%) were licensed professional teachers (LPTs). According to Kusumawardhani (2017), there is conflicting evidence on the impact of having a teaching license or certification on teacher performance. A comparison of regular certified and uncertified teachers' effects on student performance revealed that a more reliable signifier of a teacher's effectiveness is their performance during their first two years of teaching. This may imply that the teacher's performance is a reliable indicator of teacher competence as possessing a teaching license. However, in Philippine public schools, specifically in DepEd public schools, unlicensed teachers may teach through a provisional status with the condition that they pass the LET within five years of being hired (DepEd, 2016).

Most respondents taught senior high school (SHS) Biology and had 3 to 5 years (33.33%) or 6 to 10 years (33.33%) of teaching experience. New teachers with less than one year's experience constituted 18.18%, whereas those who have been teaching for more than ten years make up 9.09%. Several studies assume a linear link between teacher experience and student test scores, while others rely on categorical variables (allowing for heterogeneous teacher experience effects across categories) or distinguish solely between the initial years of experience and all subsequent years. The latter option is based on past research that suggests that only the first years of experience explain variation in student test scores (Coenen et al., 2018). In addition, compared to no significant link between content knowledge and pedagogical content knowledge, teaching experience is negatively related to curricular knowledge (Großschedl et al., 2014).

A conflicting consensus exists regarding the influence on teaching experience and teacher effectiveness. Studies show that teaching experience had little bearing on the content and pedagogical expertise development, implying that the length of teaching experience is not a guarantee of a teacher's competence. However, because teaching experience is a factor that cannot be manipulated, TPDs, especially those that are need-based and are aimed directly at improving teachers' competence, are beneficial regardless of teaching experience.

The undergraduate degree of the teacher respondents is shown in Table 1, with most being BS Nursing graduates (75.76%). Moreover, other undergraduate degrees included bachelor's degrees in Pharmacy, Physical Therapy, Animal Science, and Tourism Management. As previously described and discussed in the literature, these medical-related courses make up the bulk of CPE/DPE graduates teaching

Biology. In addition, because most health profession students seek careers in healthcare, they must complete premedical course prerequisites as part of their undergraduate education, thus many institutions' biology and life sciences curricula are heavily influenced by medical school admission requirements (Thompson et al., 2013). CPE/DPE graduate biology teachers have considerably fewer biology-focused courses than BSEd Biology or BS Biology graduates, thus the quality of biology learning might be compromised. Additionally, although BS Biology graduates comprise 12.12% of the respondents, there is a need to identify and deliver content knowledge through the appropriate teaching strategies, techniques, methods, and technology use. Therefore, a need-based TPD should be designed to enhance the teachers' TPACK.

Table 1. Teachers' undergraduate degree

Undergraduate Degree	%
Bachelor of Science in Nursing (BSN)	75.76
Bachelor of Science in Biology (BSBio)	12.12
Bachelor of Science in Pharmacy (BScPhm)	3.03
Bachelor of Science in Physical Therapy (BSPT)	3.03
Bachelor of Animal Science (BAS)	3.03
Bachelor of Science in Tourism Management (BSTM)	3.03
Total	100

Novianti and Nurlaelawati (2019) recommended that schools and universities should pay closer attention to the lecturers they have hired, particularly those without a background in education, to ensure that students receive the best possible education regardless of the staff's academic background. Furthermore, Ingersoll et al. (2014) reported that mathematics, particularly science teachers, tended to have more subject-matter content education and graduate-level education than other teachers, as well as less pedagogical and methodological training. Furthermore, the education, degree, entry path, or certificate did not make a difference, rather, the nature and content of new teachers' pedagogical preparation mattered. Therefore, the specific undergraduate degree of biology teachers is less critical. Instead, their learning and competence in biology content, pedagogy, and integrating these with technology should be examined. Non-education graduate teachers need more support, especially regarding combining content and pedagogy and integrating technology use.

Teacher Professional Development Programmes

The number of teacher professional development (TPD) programmes the biology teachers undertook was evaluated for a better understanding of their TPACK and biology teaching competence, as well as to have a basis for designing a TPD. It was revealed that many of the teacher respondents undertook from one to five TPDs focused on biology. This finding is worth noting since these biology-focused TPDs encompass the start of the teachers' careers. One or two TPDs focused on biology is insufficient since these teachers need more assistance in their content knowledge. In the same TPD category focused on biology, 12.12% of respondents received between six to ten biology-focused TPDs. Remarkably, 12.12% of respondents had not received any biology-focused TPD and none of the teachers had undertaken ten or more biology-focused TPDs (Figure 1). Therefore, this is a gap in biology teaching considering that biology, along with science in general, is a dynamic discipline with quick-paced scientific advancements.

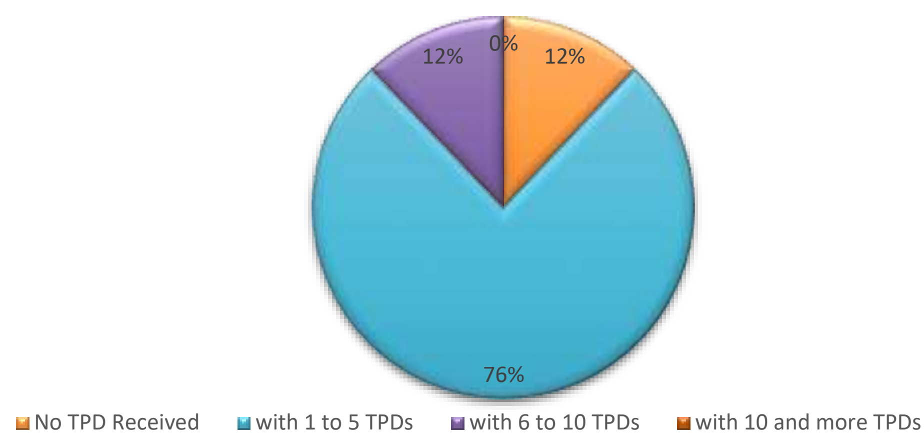

Figure 1. Biology-focused Professional Development Activities Received by the Teachers

According to Gess-Newsome et al. (2019), the average science teacher attends less than 10 hours of content-specific professional development each year. Although the possibility that this is due to the high selectivity of these learning opportunities cannot be ruled out, participation in professional development programmes is positively associated with biology instructors' content-related knowledge (Großschedl et al., 2014). This study purports to fill this gap in biology education to provide a basis for a TPD to enhance biology teaching.

Considering that TPDs help teachers enhance their competence, regular TPDs are vital, especially for in-service teachers. Every teaching contract mandates professional development which teachers attend annually (Kennedy, 2016). In the case of public schools, In-Service Training (INSET) is provided every semestral break and is usually one week long with a focus on the general rather than specialised aspects of teaching. The development and conduct of INSET programmes are at the initiative of each school division (Department of Education, 2021) and may therefore vary in terms of frequency, topic and focus, goals, and objectives, per school.

Figure 2 shows the number of TPD programmes focused on pedagogy received by the teacher respondents. These TPD initiatives focused on pedagogy include seminars and webinars, training, workshops, and other similar activities intended to enhance or update teaching.

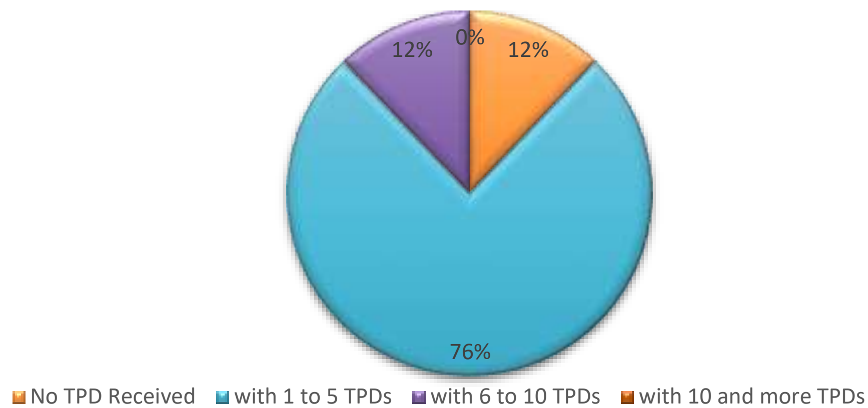

Figure 2. Pedagogy-focused Professional Development Activities Received by the Teachers

Similar to the findings on biology-focused TPDs, most respondents had between one to five TPDs focused on enhancing their teaching and teaching competence. This is a noteworthy finding considering that most teachers have been teaching for at least three years. Regarding pedagogy-focused TPDs, 12.12% of teachers received 6 to 10, 12.12% did not undertake any pedagogy-focused TPD, and no respondents received ten or more pedagogy-focused TPDs. Considering that education is constantly being reformed, there is a need to continually update pedagogy. Considering this premise and the current findings, the study intended to address such by designing and implementing a TPD focused on enhancing the teachers' biology and teaching competence. Luft (2014), described how unclear TPDs are enacted globally and that generally, science teachers have unequal access to such TPDs. Since TPDs enhance teachers' pedagogical knowledge, they are a requirement of almost every teaching contract and teachers attend TPDs annually.

The most commonly stated criterion for TPD is that it should concentrate on content knowledge. However, a review by Kennedy (2016) implies that programmes addressing any of the four enduring teaching difficulties (programme content, student behaviour, student participation, and ways to expose students' thinking) can increase instructors' efficacy and that programmes focusing solely on content knowledge had less impact on student learning. When the TPD programme focused on content knowledge was successful, the content was subsumed under a larger aim, such as assisting teachers in learning how to reveal student thinking. This implies that TPDs should not solely focus on content knowledge but rather be integrated with pedagogy, that is, TPDs must highlight pedagogical content knowledge.

Figure 3 shows the number of TPD initiatives focused on technology received by the teacher respondents. These TPD initiatives focused on pedagogy include seminars and webinars, training, workshops, and other similar activities intended to enhance their teaching through technology integration.

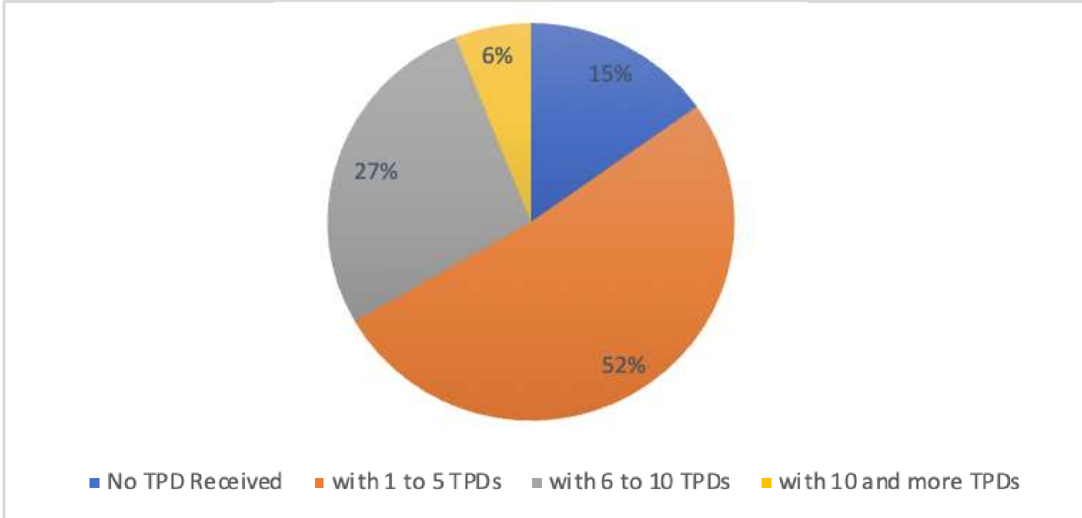

Figure 3. Technology-focused Professional Development Activities Received by the Teachers

The responsibilities placed on science teachers have changed as scientific education is reformed to meet the changing students' needs. Although there are a variety of teaching techniques that assist the development of 21st-century students, one that has received much attention in science education is the integration of technology (Jurkiewicz, 2014). Integrating technology in the form of blended learning and online education exemplifies how vital technology is in today's education. Since technology is complicated, it is viewed as more than a collection of devices that can be used but also as a way of life which provides several opportunities well as poses several challenges. The nature of technology and socially integrated media is intimately related to these difficulties and opportunities. Teachers must keep up with changing technology on a daily basis (Cloete, 2017). Through the appropriate use of information and communication technology, 21st-century learning usually involves students in collaborative work and real-world problem-solving (ICT). ICT-integrated learning may be developed to serve such pedagogical goals as a means to implement 21st-century learning in schools but teachers may not be fully prepared to do so, as empirical research shows that they primarily use ICT for content transmission (Koh et al., 2017).

Most respondents undertook one to five technology-focused PD, with 27.27% receiving six to ten, and 6.06% undertaking ten and more in contrast to biology or pedagogy-focused TPD. This is attributed to the COVID-19 pandemic leading to an unprecedented shift to online or flexible educational modes and academic institutions equipping teachers with technology-focused TPDs in response to the shift in the educational setup. However, 15.15% of the respondents have not undertaken any TPD focused on technology use. TPDs respond to the needs of teachers in the online environment, therefore they are crucial in assisting online teachers to adopt online pedagogical practices and reshaping their teacher persona in an online setting (Baran & Correia, 2014). Hence, there is a need to provide ample technology-focused TPD for the teachers.

Similarly, most teachers undertook between one to five TPDs in the span of their teaching career but this can be considered insufficient since the teachers have been teaching for between three to ten years. It is also worth noting that a significant number of teachers have not received any TPD at all. Based on these findings, there is a need to provide teachers with regular TPDs, especially those that are need-based. TPDs are beneficial, especially for in-service teachers, because these upgrade and update the teachers' teaching competence. Teachers must receive regular TPDs that are not limited to improve their teaching but equally focused on enhancing their content and technology knowledge.

TPACK of the Teachers

The TPACK framework (as illustrated in Figure 4) is categorised into core knowledge bases: technology (TK), pedagogy (CK), and pedagogy knowledge (PK), and second-level knowledge bases: pedagogical content (PCK), technological pedagogical (TPK), and technological content (TCK) knowledge. Considered an indicator of teacher quality, and therefore, the quality of education, the study identified the TPACK of the biology teachers (Table 2).

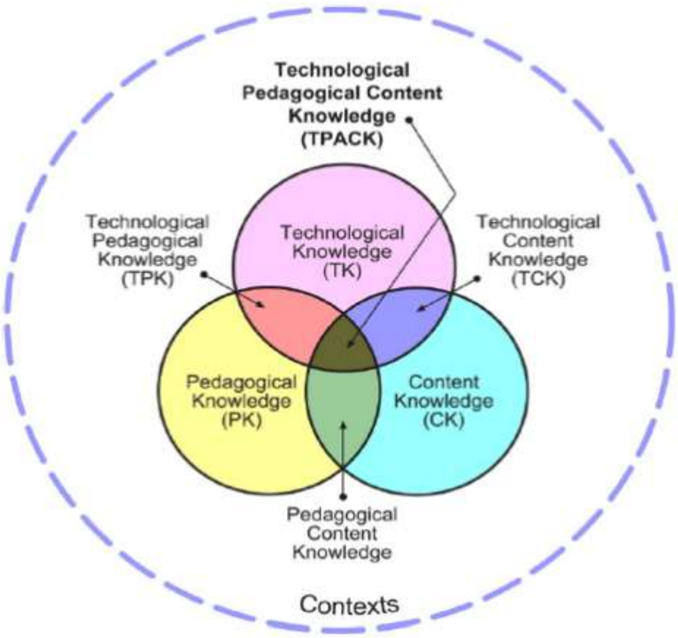

Figure 4. The TPACK Framework adapted from Koehler (2009)

Table 2. Teachers' Perceived Competence of TPACK Knowledge Bases

Knowledge Base	Weighted Mean	Verbal Interpretation
PK	3.10	Agree
TK	3.11	Agree
PCK	3.12	Agree
CK	3.13	Agree
TPK	3.16	Agree
TCK	3.25	Agree

Based on the average weighted mean per knowledge base, the respondents agreed their competence of all six TPACK components. Although the respondents positively perceived their competence regarding the TPACK components, there is still a need to further strengthen the teacher respondents' TPACK. By ranking the teacher respondents' perceptions of the TPACK components, it was revealed that the teachers perceived their pedagogical competence (PK) to be the least. Additionally, in terms of second-level TPACK knowledge bases, the teachers perceived that they were least competent in pedagogical content knowledge (PCK).

Pamuk et al. (2015) reported that second-level knowledge bases (TPK, TCK, PCK) had a greater impact on predicting TPACK development than core knowledge bases. In light of the original TPACK schema and its underpinnings, this implies that knowledge bases in the TPACK framework, particularly second-level knowledge bases, have strong correlations and predictive capacity for TPACK development. Although technology, content, and pedagogy appear to be separate and distinct knowledge bases, the interactions and connections between these knowledge bases are the essence of the whole TPACK framework. Additionally, the interaction between and among the knowledge bases is at the very core of effective teaching (Harris et al., 2009). The development of TPACK is a hierarchical model that starts with basic knowledge bases at the core, followed by second-level knowledge bases. Through the second level, the power shift from the first level to TPACK development is considerable and the first-level direct link to TPACK is ineffective. The existence of well-defined linkages between knowledge bases shows that they all have an equal impact on TPACK development (Pamuk et al., 2015).

Therefore, a need-based TPD designed to address and enhance all the knowledge bases is recommended. The second-level knowledge (PCK, TPK, TCK) encompasses the core knowledge bases. Pamuk et al. (2015) showed that TPK and TCK were statistically significant factors in explaining TPACK variance in structural equation modelling investigations. In addition, TCK stands out as the mediator knowledge base in the structural model. The TPD design aimed to enhance the PCK, TPK, and TCK of the teacher participants. However, as reflected in Table 2, because the core knowledge bases are less perceived by the respondents compared to the second-level knowledge, TK, PK, and CK were also emphasised in the training design. Hence, to ensure that the teacher participants' TPACK is enhanced, the ability of a teacher to develop teachability of the content considering learners' backgrounds, motivation, classroom management, and other factors constituting the essence of pedagogical content knowledge, is the next step after a teacher has developed a deep understanding of the content (Shulman, 1986). The respondents' perceptions of their overall TPACK are presented in Table 3.

Table 3. Teachers' Perceived Overall TPACK Competence

Technological Pedagogical Content Knowledge (TPACK)	Weighted mean	Interpretation
31. I can use technology in teaching the specific content within the defined pedagogical approach in a given context.	3.15	Agree
32. I can use technology to ease students' learning of specific content.	3.27	Strongly Agree
33. I can use technology in such a way that students feel it positive impact on their learning of specific subject matter	3.18	Agree
34. I can use technology to organise my teaching and students' learning specific content.	3.33	Strongly Agree
35. I can select specific technology for teaching specific content.	3.24	Agree
36. I can use technology to bring real-life experiences, examples, and analogies about specific content.	3.24	Agree
37. I can use technology to identify learners' individual differences on understanding of the content.	3.15	Agree
Technological Pedagogical Content Knowledge (TPACK)	**3.23**	**Agree**

Seven items represented the teacher respondents' perception of their TPACK. Teachers highly regarded two items as aspects they strongly agree that they are capable of, including where they can use technology to ease students' learning of specific content, and they can use technology to organise their teaching and student's understanding of particular content. TPACK is a theoretical framework for describing the elements of effective technology integration in teaching and learning activities and has developed as a single "unifying conceptual framework" that integrates fundamental teaching and learning dynamics with technological advancements (Pamuk et al., 2015). However, the teachers perceived the remaining items as competencies they only 'agree' to possess a mastery of, implying that there is still an avenue for them to enhance their knowledge, hence, for them to 'strongly agree' on the seven items representative of the TPACK category.

The least 'agreed' item signifying where the teachers are least competent is the item indicating the teachers' ability to use technology in teaching the specific content within the defined pedagogical approach in a given context. In many pedagogical contexts, traditional teaching approaches are being supplemented by digital tools and teachers' educational techniques do not have to change due to their use of digital technologies (Adam, 2017). Technology provides new factors to learning and teaching, forcing teachers to adapt their methods and, thus increasing the complexity of their educational approaches. The combination of instructors' use of digital tools with their instructional techniques exemplifies this double complexity (Schmidt et al., 2009), therefore, there is a need to enhance the integration of technology, content, and pedagogy to demystify such complexity.

Also, similarly perceived by the teachers' to be an item that they do not strongly agree to possess mastery is the teachers' ability to use technology to identify learners' differences in an understanding of the content. It is believed that some teachers utilise digital technologies to simply offer the knowledge they want to teach, while others use it as a transformative tool in their subject matter teaching (Harris et al., 2009). Teachers, according to Koehler and Mishra (2008), need to understand the relationship between the three types of teacher knowledge: content, pedagogy, and technology, because technology has become an important tenet of teaching and learning and, more specifically, due to its potential for improving learning and teaching processes. Thus, there is a need to strengthen the awareness that the use of technology is not limited to the transmission of knowledge but there are other essential avenues to enhance the teaching-learning process. Assessment and establishing an appropriate assessment approach, as a key component of any effective teaching and learning strategy, is a constant challenge for instructors because the assessment framework must be adequately connected with the targeted learning outcomes. Technological advancements have resulted in the expansion of online and remote learning modes, as well as new challenges (Akimov & Malin, 2020). Individuals have diverse learning styles, aptitudes, and skills, as educationalists are aware. Added to their diverse technological experiences and attitudes, as well as their access to technology, this makes the job of a digital educator more challenging (Maor, 2017). Teachers need support in this gap in the integration of technology in teaching.

These findings imply that there is a need to capacitate teachers in the varied use of technology which is not limited to delivering the topic. Technology can also be used in assessment, identifying learners' differences in understanding of the content. Thus, a TPD design should include other functions of technology not only limited to the delivery of a certain topic. TPACK items perceived by teachers to be least competent in are presented in Table 4.

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Table 4. TPACK Items Perceived by Teachers To be Least Competent In

TPACK Item	Knowledge base	Weighted Mean	Interpretation
4. I have sufficient knowledge and experience with the most recent technologies	TK	2.82	*Agree*
9. I can explain the background details of concepts, formulas, and definitions in my field	CK	2.94	*Agree*
2. I can easily solve some of the technical problems I encounter	TK	3.00	*Agree*
16. I can motivate students to engage with the content	PK	3.03	*Agree*
17. I can effectively develop a plan for teaching a specific subject matter in my field (Biological sciences)	PCK	3.03	*Agree*
24. I can use technology to identify individual differences among students	PCK	3.03	*Agree*
8. I can present the same subject matter at different levels	CK	3.06	*Agree*
10. I have adequate knowledge in explaining relations among different concepts on the subject matter	CK	3.06	*Agree*
20. I can identify students' preconceptions and misconceptions on the subject matter	PCK	3.06	*Agree*
14. I can select appropriate teaching styles for students from different backgrounds	PK	3.09	*Agree*

Ten items were identified that the teachers believed they were least competent in the TPACK Survey questionnaire. Although the integration of technology in the teaching-learning process is considered more widespread now than ever, the challenge for teachers is to adapt learning principles to the yearly, if not daily, changes that occur in educational settings because of technological progress (Maor, 2017). Since technology is universal, students can now access education anywhere, at any time, and at their own pace, so technology is considered a vital tool in enhancing teaching-learning (Turugare & Rudhumbu, 2020). Technology can support and mediate the learning process and has revolutionised the global environment of education, considerably boosting the quality of the teaching and learning experience. Teachers' perceptions about the use of technology in the classroom are shaped through training that includes technological, pedagogical, and subject knowledge taught during the teacher training process (Akkaya, 2016). The study, therefore, intended to provide support by enhancing the teacher's TPACK through a series of TPDs which are specially tailored to these teachers to strengthen biology education and ultimately, maximise learning.

While there are items in the TPACK survey questionnaire that teachers strongly agree on their competence in, most items are only agreed by the teachers that they possess competence or mastery in. This implies that a need exists to further strengthen and therefore enhance for the teachers to have a high perception of their TPACK competence. In terms of the core knowledge base, teachers perceived that they were least competent in TK and PCK in terms of the second-level knowledge base. However, it is of note that the ten least perceived by the teachers concerning their competence or mastery are not limited to one or two knowledge bases but are from varying TPACK components. This is indicative that the teachers need guidance and support not just in one or two knowledge bases but in all the knowledge bases. The study, therefore, intended to design a TPD that addressed all core and second-level knowledge bases as well as the overall TPACK category.

The teacher profiles, indicated by their professional teaching license, their teaching experience, their undergraduate degrees, and the number of TPDs focused on Biology, teaching, and technology, are summarised in Table 5. In terms of teaching licenses, both LET passers and non-LET passers are qualified to teach because the Department of Education allows for a provision. Regardless of teaching license, new teachers are guided by the PPST which promotes and advocates for TPDs to continually upgrade teaching competence. While there is a conflicting consensus on the influence of teaching experience on teaching effectiveness, teaching experience is a factor that cannot be manipulated. In this case, TPDs are beneficial because they update the teaching competence regardless of teaching experience. Most respondents were BSN graduates which further necessitates the need for TPDs, especially need-based TPDs since most nursing colleges follow a curriculum heavily influenced by medical schools which have considerably fewer biology courses. Additionally, the TPDs received by teachers may prove insufficient considering that most have been teaching for between three to ten years.

The profile of the teachers, as reflected in Table 5, necessitated for TPDs, especially a need-based one. As indicated by the literature, TPDs have the potential to fill in this teaching-learning gap by enhancing teaching competence through updating and equipping teachers with necessary skills, as revealed by the pretest measure.

Table 5. Teacher Respondents Profile

	Teacher's Profile	%
Teaching License	LET Pass	81.81
	Non LET Pass	18.19
Teacher Experience (in years)	Less than a year	18.18
	1 to 2	6.06
	3 to 5	33.33
	6 to 10	33.33
	More than 10	9.09
Undergraduate Degree	BS in Nursing (BSN)	75.76
	BS in Biology (BSBio)	12.12
	BS in Pharmacy (BScPhm)	3.03
	BS in Physical Therapy (BSPT)	3.03
	Bachelor of Animal Science (BAS)	3.03
	BS in Tourism Management (BSTM)	3.03
Teacher Professional Development Programs Received		
Biology	No TPD received	12.12
	1 to 5	75.76
	6 to 10	12.12
	10 and more	0.00
Teaching	No TPD received	12.12
	1 to 5	75.76
	6 to 10	12.12
	10 and more	0.00
Technology	No TPD received	15.15
	1 to 5	51.52
	6 to 10	27.27
	10 and more	6.06

Since TPACK is at the very core of effective teaching (Koehler, 2009), it is beneficial to assess how teachers effectively integrate technology into their content and pedagogical competence (Pamuk et al., 2015). The three knowledge bases are interwoven (Sahin, 2011), therefore, teachers' overall TPACK competence stems from their competence in all the knowledge bases. For teaching to be effective, teachers must have a high perception of their TPACK competence. Teacher PDs are regarded as a crucial tool in improving teachers' content knowledge and teaching techniques (Bautista & Ortega-Ruiz, 2015). Moreover, integrating knowledge bases with technology is challenging considering its dynamic nature. Virtually, every teaching contract requires teachers to attend annual professional development programmes (Kennedy, 2016), that is, teachers should attend at least one TPD annually focused on each of the knowledge bases.

Considering the teachers' perceived TPACK competence and their profile as represented by teaching license, teaching experience, undergraduate degrees, and the TPDs they have received, there is a gap for improvement. For both licensed and unlicensed teachers, there was no marked difference in their perceived TPACK competence or teaching experience. TPDs enhance teachers' teaching competence, specifically their TPACK, and because the teachers have undertaken few TPDs, a TPD designed according to the needs of the teachers is beneficial, therefore, there is a need to design a need-based TPD for CPE/DPE graduates teaching biology.

The Most Essential Competencies (MELCs) in Biology

This study also investigated the teachers' perceived competence in biology competencies. In addition to having a better understanding of their competence, their biology teaching competence was assessed and utilised as anchor topics in designing a TPD intended to enhance the teachers' TPACK. The MELCs are grouped into eight major learning areas including the Cell, Transport Mechanisms, Biological Molecules, Energy Transformation, Organismal Biology, Genetics, Evolution, and Taxonomy. In total, there are 27 items in the biology MELCs and Table 6 presents the teacher respondents' perceived competence in teaching the biology MELCs. The teachers' perception was represented through a response set ranging from Poor, Average, Good, and Excellent.

Table 6. Teachers' Perceived Competence of the Biology MELCs

Rank	Biology MELC	Weighted mean	Interpretation
1	Bulk/Vesicular Transport	2.42	Average
2	Facilitated Transport	2.55	Good
3	ATP- ADP Cycle	2.55	Good
4	Central Dogma of Molecular Biology	2.55	Good
5	Feedback Mechanisms	2.61	Good
6	Basic Taxonomic Concepts and Principles, Description, Nomenclature, Identification, and Classification	2.61	Good
7	Active Transport	2.64	Good
8	Recombinant DNA	2.64	Good
9	Sex Linkage	2.67	Good
10	Mitosis	2.70	Good

Ten items required enhanced teacher mastery. According to Großschedl et al. (2014), the content-related knowledge of teachers significantly impacts students' learning progress. In a study by Chavan and Patankar (2018), only a handful of the sampled higher secondary biology teachers are aware of biological concepts and can recognise and discriminate between biology facts, terminology, qualities, and concepts included in a biology textbook for eleventh graders. In addition, many students have common misunderstandings or misconceptions about biology and many abstract concepts are challenging to understand (Khan & Masood, 2015). One item obtained the lowest perception signifying the teacher respondents' mastery is interpreted as "Average". This item is the content on Bulk/Vesicular Transport from the topic Transport Mechanisms of the Cell. Similarly, from the same topic, the second least perceived by the teachers they lack mastery in is Facilitated Transport. Cell membrane transport is covered in biology classes from high school through graduate school but membrane transport is difficult to understand, so students frequently mix up distinct types of transport mechanisms (Halpin & Gopalan, 2021). Many students find it difficult to picture out processes at the molecular and cellular levels accurately, hence understanding them (McDonald & Gnagy, 2015). This is reflective of teacher competence in presenting processes at the micro level. More importantly, this is indicative that teachers also need support and strengthening in this aspect. Azqiya and Rahayu (2021) found that misconceptions about passive and active transportation processes are most common among students in the concept of membrane transport. The teacher, teaching method, learning medium, students' textbooks, and even students themselves were all factors that influenced the misconceptions that students had regarding the concept of membrane transport.

The third biology MELC perceived to be least mastered by the teachers was the ATP-ADP cycle from the Energy Transformation topic, followed by the Central Dogma of Molecular Biology. The ATP-ADP cycle is central to cellular respiration, a fundamental concept in biology that has received very little attention in studies until lately (Ummels, 2014). The confusion with everyday terms such as respiration and breathing, as well as everyday ideas about energy, the biochemical nature of the concept, which necessitates understanding at the cellular, subcellular, and molecular levels, and thus the problem of connecting these levels of biological organisation, are all examples of learning difficulties (Wierdsma et al., 2016). Furthermore, complex processes and the use of technical words make learning some topics like cellular respiration challenging because it comprises numerous abstract notions that are difficult to grasp. Many students have common misunderstandings about biology and complex processes and the use of technical jargon, such as in the case of cellular respiration, makes them difficult to comprehend (Khan & Masood, 2015).

The central dogma of molecular biology, which outlines the basic flow of genetic information inside a cell, is one of the fundamental biological principles about which students still have many misconceptions after finishing biology classes (Briggs et al., 2016). For students, the concept of genetics dictating inheritable qualities is frequently a relatively well-understood component of science. However, student comprehension suffers noticeably when it comes to genetics at the cellular or molecular level, thus the central dogma of molecular biology (basically, that genetic information passes from DNA to RNA to produce proteins) integrates chemically linked information components that are challenging for students to understand (Holme, 2021). In addition, understanding the movement of genetic information inside the cell is essential for learning about inheritance, phenotypic expression, developmental biology, and evolution at a higher level (Briggs et al., 2016). The alterations in the levels or directions of genetic information flow can lead to pathophysiological states such as uncontrolled cell division, tumour formation, and cancer, thus the central dogma of molecular biology is an important topic for undergraduate students interested in careers in medicine, allied healthcare professions, and biomedical research. Additionally, a better understanding through optimal teaching-learning of the central dogma of molecular biology is key to ending vaccine hesitancy (Holme, 2021) which is relevant in the current pandemic.

Biology teachers play a critical role in the transmission of biology content knowledge to students, therefore if biology teachers have some misconceptions or alternate conceptions about biology concepts, it will ultimately manifest in their students, negatively impacting their conceptual comprehension (Chavan & Patankar, 2018). Supporting students in the development of subject matter/content knowledge is a major challenge for teachers, even more so for non-BS biology graduates teaching biology. Thus, as shown in Table 5 and discussed above, the four contents were the topics utilized for the TPD. There is a necessity for ongoing education of in-service teachers considering that most do not enrol in continuing or graduate studies, hence there is a possibility of knowledge stagnation during their professional lives. Each of the four TPD sessions featured each of the contents as anchors particularly to enhance the teachers' TPACK. In-depth teacher education, professional development, and teacher self-study are all favourably connected to specific content-related knowledge categories (Großschedl et al., 2014).

Conclusion

Most of the DPE graduates teaching biology were licensed professional teachers, had been teaching for three to ten years and were BS Nursing graduates. In terms of TPDs focused on biology, pedagogy, and technology, most teachers had undertaken an insufficient number of TPDs. With regards to the biology teachers' TPACK, the respondents only agree on their competence in all knowledge bases and perceived that they were least competent in pedagogical competence and their pedagogical content knowledge. Overall, the teachers reported agreeing on their TPACK competence and ten biology MELCs were identified as requiring enhanced teacher competence. Therefore, there is a need to enhance the competence of CPE/DPE graduate biology teachers in their TPACK and biology MELCs, particularly all the TPACK knowledge bases. Thus, a need-based TPD anchored on the teachers' TPACK and their perceived competence in the biology MELCs is beneficial and recommended to enhance the teachers' TPACK.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

J. M. Loseñara: Data curation; Writing ─ original draft; Writing ─ review and editing. **R. R. Jugar:** Conceptualization; Formal analysis; Writing ─ review and editing.

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