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Enhancing Teachers' Technological, Pedagogical, and Content Knowledge and Biology Competence Through Need-Based Professional Development

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Annotation. This mixed-methods study, using a sequential exploration approach, investigated the impact of a need-based professional development (TPD) program on the Technological, Pedagogical, Content Knowledge (TPACK) of non-teacher education graduates teaching Biology. Results indicated significant improvement in the teachers' Biology competence and knowledge bases except for technology. The study recommends need-based TPDs to enhance teachers' TPACK, especially technology.

Keywords: *biology education, non-teacher education graduates, teacher professional development, technology knowledge, TPACK.*

Introduction

Biology education occupies a significant niche in modern-day society, as it is fundamental to environmental education, a key aspect of sustainability. Science, Technology, and Education are delicately interwoven and altogether the spine of development (Etebu & Amatari, 2020). Biology education includes vital topics for sustainable future planning such as biodiversity, climate change, health, and welfare (Jeronen et al., 2016).

Advantageously, Biology curricula are designed to provide science and technology knowledge and skills students need to solve problems and make everyday life decisions anchored on scientific attitude and noble values (Hiong & Osman, 2013). Therefore, Biology teachers play significant roles in improving biology education and its tenets. But the number of available, formally trained teachers specialized in teaching biology is inadequate.

In the process of highlighting the intended impact of biology education on sustainability and development, these studies reveal a crucial gap between curricular goals and teaching practice, particularly when there is a scarcity of formally trained biology teachers. This gap highlights the concern of whether students are actually able to acquire the intended competencies, thereby necessitating research that investigates not only content taught but also whether it was effectively delivered and the factors influencing effectiveness.

In the Philippines, an alternative way to earn professional education units and consequently be qualified to take the professional teacher licensure examination is the Diploma in Professional Education (DPE) program. Marrying content with knowledge of teaching methods and practices is unarguably an ideal concept, such as for those graduates of Biology or Agriculture. However, this is not the same for graduates from health professions. A nursing graduate who completes the DPE program is subsequently recognized as a biology major by the Professional Regulatory Commission (PRC). There are only a few biology courses in the Bachelor of Science in Nursing curriculum, not to mention subjects essential in biology teaching. Thus, DPE graduates who are graduates of bachelor's degree programs in the health profession might juggle two challenges: content and pedagogy. Although the CPE/DPE program is ideal for some non-education graduates, it is not equally the same for all. Since teacher quality impacts students' learning (Guerriero, 2014), it is beneficial to investigate teacher quality, especially DPE graduates.

The study aims to investigate the impact of a need-based teacher professional development (TPD) program on the teaching competence of Biology teachers who are non-teacher education graduates in the Philippines. Specifically, the study examines whether participation in the TPD program significantly improves their TPACK and Biology MELC competence.

Literature Review

Several indicators represent teacher quality. Guerriero (2014) identified that teacher quality is reflected by teacher knowledge, which he further specified into knowledge bases. Due to the sudden shift to online or flexible modes of education caused by the COVID-19 pandemic, biology teachers who are DPE graduates are faced with the challenge of not only integrating content and pedagogy but also technology.

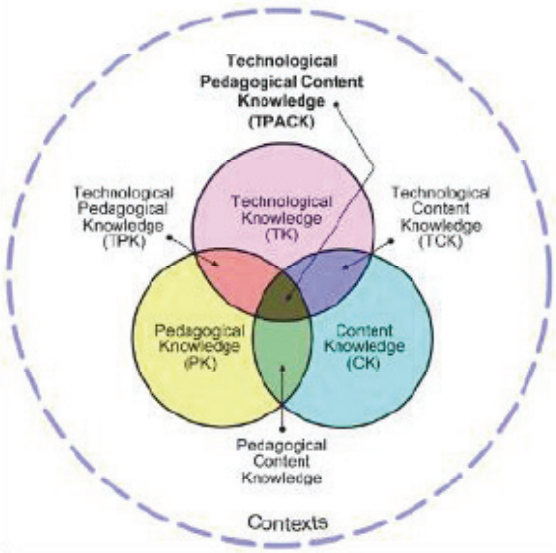
Even though the DPE program offers an alternative route for non-education graduates, specifically those from the health professions, concerns regarding its limited biology content arise, especially with regard to the readiness of the graduates to effectively teach biology. This deficiency may influence the gaps in both content and pedagogical knowledge among DPE graduates, entailing the need for targeted professional development initiatives.

Pedagogical Content Knowledge (PCK) is defined as the remarkable synergy of teaching practice and content distinct to educators (Mu et al., 2018). As a multidimensional construct, teacher knowledge includes content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (König et al., 2014). PCK combines content knowledge into pedagogy. A modification to Shulman (1987) PCK is the integration of Technology Knowledge (TK) as in Koehler & Mishra's (2008) TPACK framework.

Especially true in the 21st century, according to Koehler & Mishra (2008), Technology (TK), content (CK), and pedagogical knowledge (PK), and the relationships among these components are at the very core of good teaching. Teacher's TPACK (Technological, Pedagogical, and Content Knowledge) is the effective integration of technology in teaching (Pamuk et al., 2015). TPACK has gained interest in recent years because it answers the need for teachers to meet 21st-century skills since it highlights the integration of technology in education (Dewi et al., 2021).

Figure 1

The TPACK Framework



Note. Adopted from Koehler and Mishra (2008)

The evolution from PCK to the TPACK framework (Koehler & Mishra, 2008) reflects the increasing complexity of teacher knowledge required in modern classrooms. However, the literature is less clear on how non-traditional teacher preparation programs, such as the DPE, equip graduates with the integrated knowledge needed for effective technology use in biology teaching, indicating a gap this study seeks to address.

For any country that seeks progress, students must have teachers who possess substantial content and pedagogical knowledge (Odumosu & Fisayi, 2018). At the very core of effective teaching in today's society, Koehler & Mishra (2008) identified three components: pedagogy, content, and technology. Equally significant are the relationships between the components. The integration of technology as technology knowledge (TK) in the knowledge bases consequently established second-level constructs, including technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK.

Simply defined, TCK refers to knowledge of technology use within certain concepts, such as Biology (Valtonen et al., 2015). TCK can be viewed as a relationship where technology and content influence each other. Teachers must not only grasp the subject matter or content but also have an extensive knowledge of how content can be effectively delivered as impacted by technology (Koehler & Mishra, 2008). The knowledge of how different technologies support various pedagogical approaches is TPK which entails a general knowledge regarding all the potentials of technology in education (Valtonen et al., 2015). Koehler & Mishra (2008) defined TPK as the ability to understand how teaching and learning are affected relevant to the specific use of technologies.

In the 21st century, science teachers must be competent in integrating technology into their pedagogy. It is essential to note that TPACK is a separate unit, a distinct knowledge base, not solely an integration of the knowledge bases. When TPACK is assessed, valuable insights are provided because pedagogy, content, and technology are developed (Fakhriyah et al., 2022), ultimately improving learning.

Biology teachers, who are not teacher education graduates, are guided by the Biology Content Standards. These teachers typically acquire only professional education units through the Diploma in Professional Education (DPE) Program. As a result, there is a need to evaluate teachers' understanding of biology concepts in addition to the teachers' TPACK. Teachers' competence in biology can be evaluated using the Department of Education's (DepEd) Biology Most Essential Learning Competencies (MELCs) as detailed in the Teaching Guide, offering insights into their readiness for effective biology instruction.

Because education is constantly faced with reforms, teacher professional development (TPD) program is seen as an adaptive response to be abreast with changes in the educational setup (Bautista & Ortega-Ruíz, 2015). For today's teachers to successfully provide life-long learning amidst a continuous influx of changes, TPD is a means to equip teachers to adapt to ongoing reforms. In addition, TPD positively influences

teachers by providing job satisfaction and commitment. In the case of non-education graduates, TPD is potentially beneficial to these teachers, especially graduates of bachelor's degrees related to the health profession. While the DPE program provides professional education courses to enhance pedagogy, TPD provides such teachers with knowledge of biology content and competence in teaching biology, eventually empowering these teachers' pedagogical content knowledge through a better quality of Biology education.

Another professional development model which this study proposes to adopt is the Professional Development Model by Joyce and Showers. The Joyce & Showers model is purely for professional development, and unlike other models that are descriptions of the model, the Joyce & Showers model describes steps within one model (Rehman, 2018). Understanding how and when teachers use research and evidence to build their practice is critical to our understanding of how and when teachers use and acquire knowledge and skills evidence to improve their practice (Joyce & Showers, 2003). Their professional development strategy allows teachers to acquire and apply new knowledge and teaching skills in a way that leads to student achievement. The training's deliverables were defined by Joyce and Showers as knowledge and awareness of educational theories and practices, new curricula or academic content; positive changes in the teacher's attitude toward himself, the children to be taught, and the academic content to be transferred; development of necessary skills; and training transfer and 'executive control' (Kuijpers, 2010).

While TPD is widely recognized as essential for teacher adaptation and growth (Bautista & Ortega-Ruíz, 2015), evidence regarding its effectiveness for DPE graduates, particularly those with limited biology backgrounds, remains limited. This suggests the need for research on targeted, need-based TPD models that address specific gaps in both content and technology integration.

This study explored the impact of a need-based TPD on the teaching competence of Biology teachers who are non-teacher education graduates. Specifically, the study ought to answer the following research question: Does participation in a need-based TPD program significantly improve the TPACK and Biology MELC competence of non-teacher education graduates teaching Biology, as measured by pre- and post-tests?

Despite the recognized importance of TPACK and professional development, few studies have examined the impact of need-based TPD on the TPACK and content competence of DPE graduates teaching biology. To fill the gap, this study offers a better understanding of how to address current biology teachers' challenges and needs by effectively designing professional development programs.

Despite the considerable number of studies highlighting the importance of comprehensive teacher knowledge frameworks such as TPACK, and the positive impact of professional development programs, hardly any focus on need-based TPDs and their effectiveness on DPE graduates teaching biology. The present study intends to address

this gap by demonstrating how a need-based professional development program improves non-formally trained biology teachers.

Methodology

A mixed-method design was adopted to achieve the purpose of the study, specifically the Explanatory Sequential approach. The fundamental principle of mixed method design is the idea that researchers should gather multiple data using several varied strategies to complement the strengths of the different methods used following the combination of both quantitative and qualitative methods (Johnson, 2013). In general, this design intends the quantitative results to be supported by qualitative data through a more detailed explanation. Thus, the quantitative method is succeeded by qualitative investigation. For the quantitative part, the pre-experimental design was utilized, specifically the One Group Pre-test–Post-test approach to assess the effects of a treatment on a single group of participants (Creswell, 2018). The design allowed for a direct comparison of outcomes before and after the teachers' participation in the TPD to evaluate its impact and implications for practice.

The study employed a pre-test–post-test design involving thirty-three in-service biology teachers who participated in a need-based professional development (TPD) program. To assess participants' Technological Pedagogical Content Knowledge (TPACK) competence, the study utilized the 37-item TPACK Survey Instrument developed and validated by Pamuk et al. (2015). This instrument covers seven constructs: three core knowledge bases (CK, PK, TK), three integrative knowledge bases (PCK, TCK, TPK), and the overall TPACK. Participants rated their competence using a four-point Likert scale, where 1 corresponds to "Strongly Disagree", 2 to "Disagree", 3 to "Agree", and 4 to "Strongly Agree" with no neutral midpoint. Mean scores were interpreted within the following ranges: 1.00–1.75 as Strongly Disagree, 1.76–2.50 as Disagree, 2.51–3.25 as Agree, and 3.26–4.00 as Strongly Agree.

Pamuk et al.'s instrument has undergone rigorous psychometric evaluation, including correlation analyses and structural equation modeling (SEM), which demonstrated strong construct validity and reliability. The SEM results indicated significant correlations among TPACK components, with TPK and TCK exerting a strong influence on overall TPACK variance. Reported Cronbach's alpha coefficients for the instrument's subscales consistently exceeded 0.80, confirming high internal consistency. These findings support the appropriateness of the instrument for assessing TPACK in in-service teachers.

In the study, the instrument was adapted without modification to preserve its validated structure and psychometric properties. Although sample-specific reliability

coefficients were not recalculated due to the limited sample size, the original validation provides a robust foundation for its reliability and validity in our context.

In addition, teacher competence in Biology Content Standards was assessed using a self-rating instrument aligned with the Department of Education's (DepEd) Most Essential Learning Competencies (MELCs) for Biology. This instrument employs a four-point agreement scale and reflects the official curriculum standards, ensuring content validity. The Biology Content Standards instrument was administered alongside the TPACK survey in both pre-test and post-test phases.

The study followed a need-based approach wherein the TPD was developed through developmental sequencing; that is, the TPD was designed based on the needs or results of the pre-test measure. Anchored on Joyce and Showers' model, the TPD comprised four steps: theory, demonstration, practice, and coaching. These steps in the TPD designed, singly and integrally, were intended to enhance the teachers' TPACK. The TPD consisted of multiple encounters. Before its implementation, the TPD program plan underwent expert validation by three expert validators.

The post-test measure was administered to eight teacher participants who voluntarily participated and completed the TPD. Wilcoxon Signed-Rank Test was employed to establish whether there was a significant difference in the teachers' TPACK before and after their participation in the TPD. When comparing paired observations from two populations, the Wilcoxon Signed-Rank test is useful (Ohyver et al., 2019). Furthermore, the signed-rank test is preferred to the sign test, which is nonparametric but has significantly lower power (Benavoli et al., 2014).

In addition, the effect size is supplemented to determine the influence of an intervention or the strength of a relationship between two or more variables (Téllez et al., 2015). Cohen's d, a standard test to identify effect size, was used in the study. Cohen's d is one of various statistics used to investigate mean differences (Diener, 2010), as in this case, the difference in mean outcome between the teachers' TPACK and Biology MELCs competence before and after the TPD.

In addition to the pre and post-test findings, the study employed a multiple-case study approach wherein, three cases were identified for follow-through to ascertain changes after the TPD. A research method, a case study thoroughly investigates one or a few cases of a phenomenon. Focusing on three purposefully selected teacher participants, a multiple-case study approach was employed to examine the detailed effects of the TPD. The cases were identified based on their participation in the TPD, initial experience with technology integration, and openness to share reflections. The semi-structured interviews, in consonance with the study objectives, probed teacher participants' experiences with the TPD, highlighting changes in their TPACK, Biology content knowledge, teaching practices and identified student learning impact. Guided by Braun and Clarke's (2006) six-step process, the verbatim transcripts were created and then analyzed through thematic analysis. Coding, identifying themes and sub-themes,

and tracing their relationships were conducted for a thorough analysis of data. Ethical considerations, including informed consent and ensuring anonymity, were observed in the conduct of the study.

Utilizing a mixed method approach, the study provides a comprehensive evaluation of the effectiveness of the TPD; the quantitative data offer a broad exploration of the impacts of the TPD, while the qualitative insights allow for an in-depth understanding of the teachers' experiences. Document analysis, including the teachers' lesson plans and instructional materials were also explored.

Results

Teachers' Overall TPACK

Items in the overall TPACK category are reflective of the integration of the pedagogy, content, and technology. Therefore, each item is presented as per Table 1 since these reflect teachers' overall TPACK competence. Findings presented in Table 1 indicate that the increase in the teachers' overall TPACK is practically significant. As indicated by the increased means in the post-test, there was an increase in the teachers' perceived TPACK competence. At a significant level of 0.05, four of the seven items in the category were found to significantly differ. This implies an increase in the teachers' perceived TPACK competence after the TPD. These items include items 32, 34, 36, and 37 ($Z = -2.00$; $p = .046$). It was revealed that there was an overall significant difference in the teachers' TPACK competence ($Z = -2.03$; $p = 0.42$), specifically an increase in their perceived TPACK competence ($M = 3.00$; $SD = .00$ to $M = 3.44$, $SD = .43$). Likewise, there was an overall large effect size ($d = -1.45$).

Table 1

Teachers' TPACK Before and After the TPD

TPACK Item	Before (n = 8)		After (n = 8)		Test		Effect Size	
	M	SD	M	SD	Z	p- value	d	
31. I can use technology in teaching the specific content within the defined pedagogical approach in a given context.	3.00	.00	3.38	.51	-1.73	.083	---	---
32. I can use technology to ease students' learning of a specific content.	3.00	.00	3.50	.53	-2.00	<0.46	-1.33	Large

TPACK Item	Before (n = 8)		After (n = 8)		Test		Effect Size	
	M	SD	M	SD	Z	p- value	d	
33. I can use technology in such a way that students feel it positive impact in their learning of specific subject matter.	3.00	.00	3.36	.52	-1.73	.083	---	---
34. I can use technology to organize my teaching and students' learning specific content.	3.00	.00	3.50	.53	-2.00	<.046	-1.33	Large
35. I can select specific technology for teaching specific content.	3.00	.00	3.37	.52	-1.73	.083	---	---
36. I can use technology to bring real-life experiences, examples, and analogies about specific content.	3.00	.00	3.50	.53	-2.00	<.046	-1.33	Large
37. I can use technology to identify learners' individual differences on understanding of the content.	3.00	.00	3.50	.53	-2.00	<.046	-1.33	Large
Overall Mean	3.00	.00	3.44	.43	-2.03	<.042	-1.45	Large

Note: Mean score interpretation ranges are: 1.00–1.75 = Strongly Disagree; 1.76–2.50 = Disagree; 2.51–3.25 = Agree; 3.26–4.00 = Strongly Agree. Statistical significance is indicated at $p < .05$. Effect size interpretations follow Cohen's d benchmarks: Small (0.2), Medium (0.5), Large (0.8).

Teachers' perception of their competence in using technology to ease students' learning of a specific content, has been enhanced after they participated in the TPD. Students' learning and engagement are enhanced when technology is used. Students find content more interesting when it is aided by technology. Knowledge transfer becomes very easy and convenient, as well as effective (Raja & Nagasubramani, 2018).

Three items in the TPACK category, although enhanced based on the comparison between the teachers' perception before and after the TPD, were found not to have a significant difference.

Teachers' TPACK Knowledge Bases

To have a better understanding of the training effect, the teachers' perceived competence in each of the TPACK knowledge bases is presented in Table 2.

The findings presented in Table 2 reveal that there was an increase in the teachers' perceived competence in all six knowledge bases, both core and second level, except for TK, had large effect sizes, indicating that the TPD is broadly effective in enhancing

these knowledge bases. However, one knowledge base was identified to have no statistically significant change between the pre-test and the post-test scores.

Table 2

Teachers' TPACK Per Knowledge Base Before and After the TPD

Knowledge Base	Before (n = 8)		After (n = 8)		Test		Effect Size	
	M	SD	M	SD	Z	p- value	d	
Pedagogical (PK)	2.88	.27	3.31	.39	-2.03	<.042	-1.28	Large
Technological (TK)	2.97	.21	3.19	.39	-1.72	.084	---	---
Pedagogical Content (PCK)	2.92	.15	3.25	.29	-2.04	<.41	-1.42	Large
Content (CK)	2.92	.15	3.20	.09	-2.57	<.010	-2.26	Large
Technological Pedagogical (TPK)	2.97	.09	3.40	.32	-2.26	<.024	-1.82	Large
Technological Content (TCK)	3.00	.00	3.43	.44	-2.03	<.042	-1.38	Large

Note:. Mean score interpretation ranges are: 1.00–1.75 = Strongly Disagree; 1.76–2.50 = Disagree; 2.51–3.25 = Agree; 3.26–4.00 = Strongly Agree. Statistical significance is indicated at $p < .05$. Effect size interpretations follow Cohen's d benchmarks: Small (0.2), Medium (0.5), Large (0.8).

Teachers' Technology Knowledge

Comparing the pre-test and post-test scores, Technology knowledge had an increase M = 2.97 (SD = .21) to M = 3.19 (SD = .39). However, only TK did not have a significant difference. This finding was observed at 0.05, indicating no significant difference (Z = -1.72, p = .84). This implies that following the teachers' participation in the TPD, their perception of their TK did not significantly change, as they still perceived their technology knowledge to be at the same level. To understand this finding, Table 3 presents the pre-test and post-test measures of the items comprising the TK base.

Table 3

Teachers' Perceived Competence of Their Technology Knowledge

Technology Knowledge	Before (n = 8)		After (n = 8)		Test		
	M	SD	M	SD	Z	p- value	
1. I can learn technology easily.	3.25	0.46	3.37	0.51	-1.00	0.317	Not Significant
2. I can easily solve some of the technical problems I encounter.	2.87	0.35	3.00	0.53	-0.52	0.564	Not Significant
3. I know how to seek technology help.	3.00	0.00	3.25	0.46	-1.41	0.157	Not Significant
4. I have sufficient knowledge and experiences with the most recent technologies.	2.75	0.46	3.12	0.35	-1.73	0.083	Not Significant

Note: Mean score interpretation ranges are: 1.00–1.75 = Strongly Disagree; 1.76–2.50 = Disagree; 2.51–3.25 = Agree; 3.26–4.00 = Strongly Agree. Statistical significance is indicated at $p < .05$. Effect size interpretations follow Cohen's d benchmarks: Small (0.2), Medium (0.5), Large (0.8).

These quantitative results were supported by interview responses, in which teachers described their experiences with the technology component of the TPD.

> *"Yes, the best part of these sessions or is is actually the technological aspect, because I can really sense that we are leaning to we are leaning to the fact that students are more technologically inclined, and using this technology in learning would really help them enjoy learning more than just discussing than the traditional ones. So here, with a technological part, I really appreciate the session, because in my case, I have not encountered those, that technology, and definitely it can really help in making learning more fun and enjoyable to my students."* (Teacher 1)

> *"Well, for technology, I must say that I'm just a mediocre in terms of how to use technology. I may not be a newbie, but I'm not also an expert. So maybe I'm just in the middle. Well, for me, the TPACK training introduced different strategies or different technology which is something that needs practice and constant use."* (Teacher 2)

Teachers' Competence of the Biology MELCs After the TPD

Comparing the data before and after the TPD, as seen in Table 4, there is an increase in the teacher's perceived competence in the topic of ATP-ADP Cycle M =1.75 (SD = .70) to M = 2.75 (SD = 1.16). In the design and implementation of the TPD, four Biology Most Essential Learning Competencies by the Department of Education (DepEd Biology MELCs) were identified as anchor topics of the TPD sessions. These Biology MELCs were determined as the four Biology MELCs regarded by the teachers in which they are least competent. The sessions were anchored on the following DepEd Biology

MELCs: (1) ATP-ADP Cycle, (2) Facilitated Transport, (3) Bulk/Vesicular Transport, and (4) Central Molecular Dogma of Molecular Biology. Pre-test and post-test findings are presented together with the non-parametric Wilcoxon Signed-Rank test results. Table 4 shows the impact of the TPD on the identified Biology MELC.

Based on the comparison between the pre-test and post-test measures (M = 1.75, SD = .70 to M = 2.75, SD = 1.16), it was revealed that there is a statistically significant difference between the pre-test and post-test results at a significance level of 0.05 (Z = -2.27, p = .023) with a large effect size (d = -1.04). MELC1 is one of the two MELCs shown to have been greatly enhanced after the TPD since the teachers regarded their competence in such topics as 'poor' to 'good' after the TPD. The result of comparing the pre-test and post-test results is suggestive that Session 4 is effective in enhancing the teachers' competence in the ATP-ADP cycle.

Table 4

Teachers' Perceived Competence of the Biology MELCs Before and After the TPD

Biology MELC	Before (n=8)		After (n=8)		Test		Effect Size	
	M	SD	M	SD	Z	p- value	d	
ATP-ADP Cycle	1.75	0.70	2.75	1.16	-2.27	<.023	-1.04	Large
Facilitated Transport	1.75	0.70	2.75	1.16	-2.27	<.023	-1.04	Large
Bulk/Vesicular Transport	1.87	0.83	2.87	.83	-2.53	<.011	-1.20	Large
Central Dogma of Biology	1.87	0.99	2.62	1.18	-2.12	<.034	0.68	Medium
Overall Mean	**1.81**	**0.72**	**2.75**	**1.04**	**-2.55**	**<.011**	**-1.05**	**Large**

Note: Mean score interpretation ranges are: 1.00–1.75 = Strongly Disagree; 1.76–2.50 = Disagree; 2.51–3.25 = Agree; 3.26–4.00 = Strongly Agree. Statistical significance is indicated at p < .05. Effect size interpretations follow Cohen's d benchmarks: Small (0.2), Medium (0.5), Large (0.8).

Overall, in comparing the pre-test and post-test results, there was an increase in the teachers' perception of their competence (M = 1.81, SD = .72 to M = 2.75, SD = 1.04) with a large effect size (d = -1.05). There was a significant difference in the teachers' perceived competence in the Biology MELCs before and after their participation in the TPD (Z= -2.55; p=.011.

These findings were further supported by qualitative responses, in which teachers reflected on how the TPD deepened their understanding of specific biology topics.

> *"Uhmm more than the expected, I think sir, because I didn't think that I would be able to learn those lessons from very good professors. I think I appreciate it very much because I haven't met those kinds of people that are so profound with biology. And in my case, I'm not that into biology Sir. So, I was really amazed. And that's why that's the reason, I've never been absent from the session…It has deepened my knowledge of the topics."* Teacher 1

"I believe that it has truly improved the way I understood things. Well, it's not new to you that I am a DPE graduate just like you. I was a nurse by profession, and I tried shifting from one profession to another. This has made different barriers in terms of teaching, because it's not the core that I was used to in college. But certainly, with this TPACK sessions, I was able to improve my learning. I'm not saying that I don't have prior knowledge to it, I do have prior knowledge to it. But the in depth understanding of the different topics is something that I have discovered. …there are certain things that are new to me, I was introduced with a deeper level of understanding a deeper extreme comprehension, especially that our speakers are expert with their areas, and I'm so glad to be able to, to know them to be able to be to understand from them and from their experience from their expertise. (Teacher 3)

Qualitative Findings

To complement the quantitative results, qualitative feedback was gathered from teachers through open-ended survey responses and reflective statements following the TPD. Thematic analysis of these responses revealed several key insights:

Theme 1: Enhanced Confidence and Willingness to Integrate Technology

Several teachers expressed increased confidence in using technology to support biology instruction after participating in the TPD. This theme includes both increase in motivation and a sense of improvement in perceived competence in technology integration.

Sub-theme 1.1: Increased Motivation

"I used to hesitate when it came to integrating technology in my lessons, but after the training, I feel more equipped and motivated to use digital tools."

Sub-theme 1.2: Improved Perceived Competence

"The TPD helped me see how technology can make abstract biology concepts more concrete for my students."

Theme 2: Persistent Challenges with Specific Biology Concepts

Despite improvements, some teachers reported ongoing difficulties with certain Biology MELCs, particularly the Central Dogma and facilitated transport.

Sub-theme 2.1: Central Dogma Complexity

One teacher shared, "Even after the sessions, I still find it challenging to explain the Central Dogma, but the examples and discussions gave me new approaches to try."

Sub-theme 2.2: Facilitated Transport Difficulties

Another teacher stated, "Facilitated transport remains a complex topic for both me and my students, but I now have more strategies to make it understandable."

Theme 3: Value of Peer Collaboration and Shared Practice

Teachers highlighted the benefit of collaborative learning during the TPD, noting that sharing experiences and strategies with peers was particularly valuable.

Sub-theme 3.1: Practical Ideas from Colleagues

As one participant reflected, "Learning from other teachers' experiences gave me practical ideas I can apply in my own classroom."

Sub-theme 3.2: Supportive Professional Community

Another participant noted, "The group discussions made me realize that others face similar challenges, and we can support each other."

Theme 4: Perceived Impact on Student Engagement

Some teachers observed that new teaching strategies with technology integration led to increased student engagement.

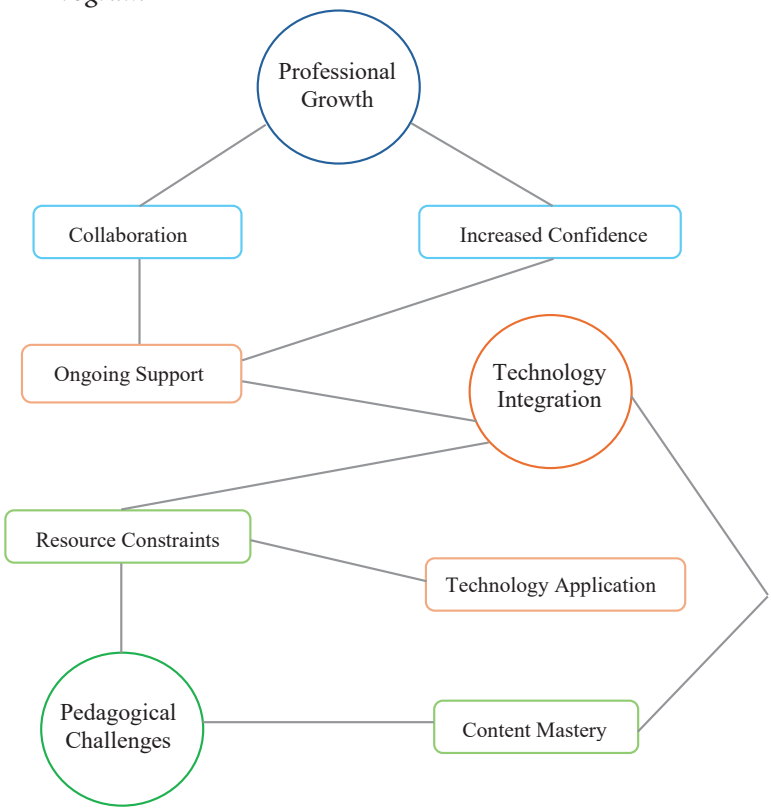
Sub-theme 4.1: Enhanced Student Interest

A teacher shared that when she used interactive activities and videos in class, her students were more interested and more active.

Essential perspectives on the observed teacher competence improvements are offered by the qualitative insights, highlighting not only areas of growth and positive influence of collaborative professional development but also areas of ongoing challenges.

Figure 2

Thematic Map of Main Themes and Sub-themes Identified From Qualitative Analysis of the TPD Program



The thematic map visually illustrates the connections among the three main themes and their sub-themes. Bridging sub-themes such as Ongoing Support and Resource Constraints link main themes, which represent the interplay between teacher development, technology use, and pedagogical challenges following the TPD.

Discussion

Teachers' Overall TPACK

Teachers' perception of their competence in using technology to ease students' learning of content, has been enhanced after they participated in the TPD. Students' interest and engagement in the content, and overall, their learning is increased with technology. Knowledge transfer then becomes easy, convenient, and effective (Raja & Nagasubramani, 2018).

The teachers' perception that using technology organizes their teaching and students' learning of specific content has been enhanced. Technology enables teachers to do tasks differently than they did before implying that technology use aids students to improve their understanding and retention of content (Raja & Nagasubramani, 2018).

Bringing practical experiences, analogies, and examples about specific content has also been enhanced. The teachers' competence in using technology to identify students' differences in understanding the content was also enhanced. Ongoing assessments of the effectiveness of instructional practices can be done using technology. Technology aids in identifying students' individual needs, which can also be addressed using technology (Nepo, 2017). Technology allows for a deeper understanding of the content and to differentiate instructional materials based on individual student needs (McKnight et al., 2016). Technology has also opened the possibility of differentiated and individualized learning for students.

There is a need to further strengthen teachers' competence in using technology to teach specific content in the specified pedagogical approach in each context. There is also a need to enhance the teachers' competence in choosing specific technology for teaching content. Teachers sought and needed professional development in the use of a specific technology and how to effectively integrate it into the classroom (McKnight et al., 2016).

Overall, the teachers' perceived competence of their TPACK has significantly increased after the TPD. This implies that the TPD has contributed to enhancing their TPACK, although there are items that need further strengthening.

Teachers' TPACK Knowledge Bases

One knowledge base, Technological Knowledge (TK), was identified to have no statistically significant change between the pre-test and the post-test scores. Despite this, findings revealed that all knowledge bases. While further research is warranted

to explore strategies for improving TK, the overall results suggest the TPD's positive impact on teacher competence

Teachers' Technology Knowledge

Although there was an increase in the post-test results, there was no significant difference before and after the teachers' participation in the TPD. All the items in the TK category were revealed to not have a statistically significant difference. This could be attributed to the fact that technology is broad and wide-ranged since it covers low to high-tech devices (Wang et al., 2018). Learning and teaching technology is challenging because technology is dynamic and new technologies bring new challenges (Koehler & Mishra, 2008). A study by Nielsen et al. (2015) found that though teachers were motivated to create and deliver technology-rich scientific discussions, various challenges hindered the implementation. Teachers are challenged with the swift expansion of technology, which demands teachers to use technologies in their teaching. Because technology is dynamic, the need for teaching training also increases (Raja & Nagasubramani, 2018).

In a study by You et al. (2021) participated by science teachers that revealed the effectiveness of a TPD, the teachers identified that the absence of training is one of the major difficulties in using technology for teaching. An effectively designed PD fosters access to knowledge and skills to advance the use of technology and instructional materials to use it effectively in teaching. In addition, globally, teachers struggle to find the most effective ways to integrate technology into their classrooms (Carver, 2016). Although the TPD program intended to address technology by having a dedicated section for technology, which is also true for all the other knowledge bases, only TK did not have a significant difference after the TPD. Certain logical factors, such as limited time, lack of access to both hardware and software, awareness of available information, shortage to no access to technology resources, computer labs, and computer technicians, and well as personal views of technology use being frustrating or too dynamic, and resistance to changes, hinders teacher's use of technology. To better understand the findings, items in the TK category are investigated.

TK Item 1 highlights the teacher participants' competence to learn technology easily. Although there was an increase in their perception, it was found not statistically significant. The TPD introduced technologies that might be primarily new to the teachers. With the presumption that learning something new is challenging, teachers might have overlapping preconceptions about their previously learned technology and the impression that technology is complicated. Learning anything new is mostly not easy, especially in the case of technology. Although the TPD informed and trained teachers of new technologies, it takes constant practice to ensure mastery and easy manipulation of the technology. Teachers' prejudice against technology use causes reluctance and in

turn, causes computer-based projects to fail. Time, access, resources, knowledge, and support are frequently reported obstacles (Raja & Nagasubramani, 2018).

TK item 2 involves the teachers' competence to solve technical problems they encounter easily. Teachers' low perception of the item is expected since technology is complicated and broad and thus entails an array of or even limitless problems that might be encountered. The TPD introduced and trained teachers in using technologies in their teaching and learning them is challenging. Learning how to solve technical problems or errors requires different and separate training. Even if the teachers can solve technical problems, solving them efficiently might not be the case. The lack of technical assistance is the leading barrier to technology use (Ghavifekr et al., 2016). Teachers cannot expect to overcome barriers to technology use without competent technical support. Separate training and workshops on technology use, specifically on basic troubleshooting, would therefore prove beneficial to the teachers.

The third TK item states that teachers know how to seek technological help. Knowing an IT personnel or a technology-savy individual is challenging for the teachers; moreover, reaching out to such a person might not be possible. Also, because the teachers come from various places in Cebu, identifying people who can help them with technology is difficult. In addition, it is noteworthy to know that technology help is broad as it covers hardware and software and even the use of technology. Two significant barriers to integrating technology into their teaching, according to Hsu (2016) are the lack of teachers' technical training and exposure, and technical support (e.g., internet speed, and non-working PCs).

TK item 4 emphasizes teachers' sufficient knowledge and experience with the latest technologies. The TPD aimed to impart knowledge and skills to the teachers with the most recent technologies. However, this is limited since the TPD was based on identified Biology MELCs. Further, learning several new technologies might be tasking as a corollary to TK item 1. In the TPD, each Biology MELC was taught by introducing and training teachers on one specific technology for each MELC. Thus, sufficient knowledge and experience entail a considerable time in terms of learning and using the most recent technologies. In a world where laptops, tablets, computers, and smartphones are increasingly viewed as the technology of choice, it could be said that humanity has reached a tipping point when education must adapt to new options (Biletska et al., 2021). New technologies mean new teacher training needs (Raja & Nagasubramani, 2018). The education system is constantly challenged by the need to expand and update the methods of training teachers (Biletska et al., 2021).

The results of the TK of the teacher participants following the TPD showed enhancement, although this change was not significantly different. Because technology is dynamic and broad, learning technology might be challenging. As evidenced in the excerpts, teachers reported that the most exciting aspect of the TPD was the introduction of new technologies. This could imply that teachers are aware of the need to learn

and adopt new technologies but have not had opportunities to do so. Technologies introduced are new to the teachers, thus, learning them takes a considerable length of time and practice.

According to McKnight et al. (2016), the way technology facilitates teaching and learning is what determines a successful technology integration. When using computer technology in the classroom, teachers must draw on the knowledge foundation that supports teachers' learning to teach (Subramaniam, 2016). Biology teachers must successfully integrate technology into their teaching to improve e-readiness skills and metacognition to help lessen misconceptions of topics in biology (Jamaluddin et al., 2023). Compared to the second-level knowledge bases, the direct impacts of the core knowledge bases are smaller (Pamuk et al., 2015). Teachers also reported that the technologies introduced will be used in their teaching, and through constant use, they will be able to integrate content and pedagogy smoothly.

In addition to enhancing the teachers' technology knowledge, enhancing TCK and TPK, and overall TPACK should be emphasized since these knowledge bases signify a more critical aspect, technology integration in the teaching-learning process. Equally important than concentrating on how technology enhances students' learning of science material, it is important to focus on the pedagogical practices established with the integration or usage of technology, anchored on the teachers' own understanding of classroom situations and curriculum (Subramaniam, 2016). Being able to adapt and integrate technology is a pedagogy that brings fun and meaningful learning, thus, better quality and effective learning (Nurdin et al., 2023)combining qualitative and quantitative data analysis. The study results show that digital transformation strategies can create teachers' learning management that is fun, meaningful, full of creativity, and effective in terms of time and cost. The findings in this study are: owing to beginner-like technology practices, integrating technology and all other components of the TPACK may entail considerable work to support teachers incorporate the knowledge bases (Morales et al., 2022). Based on the findings, need-based TPDs are therefore beneficial.

Teachers' Competence of the Biology MELCs After the TPD

Findings reveal a significant difference between the pre-test and post-test findings at a significance level of 0.05 ($Z = -2.27$, $p = .023$) with a large effect size of ($d = -1.04$). Another Biology MELC that the TPD has greatly enhanced is the topic of Facilitated Transport. This is supported by a significant difference between the pre-test and post-test findings which also indicates a large effect size. This finding implies that Session 2 of the TPD could be used to enhance teachers' TPACK concerning Facilitated Transport.

The teachers' competence in the Biology MELC3: Bulk/Vesicular Transport and Biology MELC4: Central Dogma of Molecular Biology was also found to have been enhanced ($M = 1.87$, $SD = .83$ to $M = 2.87$, $SD = .83$), ($M= 1.87$; $SD = .99$ to $M = 2.62$; $SD =$

1.18) respectively. A significant difference in both Bulk/Vesicular Transport (Z = -2.53; p = .011) and Central Dogma of Molecular Biology (Z = -2.12; p = .034) is also noted.

The teachers' competence in Biology MELC3: Bulk/Vesicular Transport and Biology MELC4: Central Dogma of Molecular Biology was also found to have been enhanced. A significant difference in both Bulk/Vesicular Transport and Central Dogma of Molecular Biology is also noted. The session on Bulk/Vesicular Transport had a large effect size. The Central Dogma of Molecular Biology session had a medium effect size. This is suggestive that the session can still be improved. However, the medium effect size still entails practical significance considering that a significant difference exists in the teachers' perceived competence after they participate in the TPD session.

Teachers shared that the TPD has indeed provided them with a better understanding of the content, if not, it has refreshed their content knowledge. As previously noted in the excerpts, the teachers considered the TPD to have impacted their content knowledge, especially because it has enriched or deepened their knowledge on the topics discussed in each of the sessions.

Based on the findings, the teachers' competence in the identified Biology MELCs was enhanced. Also, overall, with a large effect size, the TPD is recommended to enhance teachers' competence in the identified Biology MELCs. Numerous strategies supporting student learning, as well as integrated learning environments, have been paved by educational technology advancements (Yang et al., 2021). Teacher competencies and practices are strengthened by TPDs and are therefore recommended (Sabah et al., 2023).

Qualitative Findings: Insights and Implications

A more refined understanding of the observed improvements in the teachers' competence has been highlighted through the qualitative insights. Following the thematic analysis, four themes emerged, namely improved confidence and willingness to integrate technology, ongoing challenges with biology concepts, the value of collaborating with peers, and the positive influence on student engagement.

Enhanced Confidence and Willingness to Integrate Technology

Teachers stated increased motivation and perceived competence in using technology, which aligns with the significant increases shown in the TPACK post-test scores. As a teacher reported, "I used to hesitate when it came to integrating technology in my lessons, but after the training, I feel more equipped and motivated to use digital tools." This supports prior research indicating that need-based professional development can boost teachers' confidence and skills in technology integration (Raja & Nagasubramani, 2018; McKnight et al., 2016).

Ongoing Challenges with Specific Biology Concepts

Though overall enhancements were noted, teachers continued to face challenges with complex topics including Central Dogma and facilitated transport. Drawing from findings on existing teacher professional development studies, this theme highlights the

need to address challenging areas by providing continual support and proper resources alignment.

Importance of Peer Collaboration and Shared Practice

The importance of peer collaboration was a key theme because teachers reported an emphasis on sharing practical ideas and collaborative support. This is in consonance with literature highlighting that participation in professional learning communities significantly influences teacher development (Vescio et al., 2008).

Influence on Student Engagement

When teachers applied new technologies and strategies, it was evident that students' interest and participation increased. This is in line with study findings supporting TPACK increase technology influence in enhancing student engagement (Nepo, 2017).

The thematic map, presented in Figure 2, emphasizes how Professional Development, Technology Integration, and Pedagogical Challenges are closely connected with the other sub-themes of Ongoing Support, Collaboration, and Resource Constraints. These connections signify that peer collaboration and sufficient resources were instrumental to the improvements in teachers' TPACK and competence. Contrastingly, limited resources caused a lack of significant enhancements in Technology Knowledge. This underscores the need to design TPDs that not only focus on instruction but also address the need for continual support and useful resources, enabling teachers to effectively integrate technology.

Implications

As qualitative insights reinforce the quantitative results, areas for improvement, including the need for ongoing support with challenging content, and sustained initiatives to establish professional learning communities, are revealed.

Conclusion

This study, anchored on the TPACK framework, explored the impact of a need-based professional development program on teachers' TPACK. This is crucial in biology education where the integration of content, pedagogy, and technology is essential. The study findings offer significant insights of the impacts of a need-based Teacher Professional Development (TPD) program to non-education graduate Biology teachers especially on their teaching competence. The results of the study revealed a substantial enhancement in the overall TPACK of the teachers from their TPD participation, with improvements in most of the knowledge bases. Nonetheless, no significant changes were observed in the teachers' technological knowledge (TK). Complementing the quantitative findings, the qualitative insights further elucidate the teachers' experiences which highlight an

increase in confidence in technology use, ongoing challenges with biology concepts, the importance of peer collaboration, and the positive influence on student engagement. These enhancements are indicative of the TPD's effectiveness in improving the biology teachers' competence to integrate pedagogy and content. However, findings also reveal the need for additional support aimed to strengthen teachers' technology knowledge. As revealed by the thematic analysis, ongoing support, peer collaboration, and resources availability significantly fostered enhancements and effectively addressed challenges in technology adoption. Teachers' competence in the Biology MELCs was also enhanced by the TPD. This enhancement in the teachers' competence is evident in both the pre-test and post-test scores and the qualitative insights where teachers reported increase in confidence and competence in their teaching. The study shows that need-based TPD programs positively influence the teaching competence of non-education graduate Biology teachers, especially in their pedagogical and content knowledge.

The study advances the TPACK literature by establishing the effectiveness of need-based professional development in improving teachers' TPACK and by looking into the significant link between TPACK enhancement and competence in aligning their teaching with curriculum standards. Essentially, the study recognized that non-education graduates teaching Biology represent a specialized group that generally needs targeted support in pedagogical and technological expertise. Therefore, the study designed, implemented, and evaluated a need-based TPD, providing invaluable insights for educators and policymakers who intend to address these unique professional development needs and consequently improve teaching effectiveness through targeted training in technology integration.

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Mokytojų technologinių, pedagoginių ir dalykinių žinių bei biologijos kompetencijų stiprinimas taikant į poreikius orientuotą profesinį tobulinimąsi

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Santrauka

Mokytojai, taip pat ir tie, kurie nėra baigę pedagogų rengimo studijų, susiduria su iššūkiu integruoti ugdymo turinį, pedagogines ir technologines žinias. Šiuo mišriu tyrimu tirta poreikiais grindžiamos profesinio tobulėjimo (angl. TPD) programos poveikis biologijos mokytojų, neturinčių pedagoginio išsilavinimo, technologinėms, pedagoginėms ir turinio žinioms (angl. TPACK). Tyrime buvo taikomas tiriamasis nuoseklusis dizaino metodas, siekiant įvertinti TPD poveikį, atsižvelgiant į trisdešimt trijų pedagoginio išsilavinimo neturinčių biologijos mokytojų poreikius. Po TPD buvo įvertintas aštuonių mokytojų TPACK, o dokumentų analizė ir tolesni interviu su trimis dalyviais leido surinkti kokybinius duomenis apie programos poveikį. Esant 0,05 reikšmingumo lygiui, buvo nustatyta statistiškai reikšmingų žinių bazės skirtumų, išskyrus technologijų žinias ($Z = -1{,}72$, $p = > 0{,}084$). Rezultatai parodė, kad TPD žymiai pagerino mokytojų kompetenciją biologijos MELC ($Z = -2{,}55$; $p = < 0{,}011$) ir jų bendrą TPACK ($Z = -2{,}03$; $p = < 0{,}046$) esant dideliam poveikio dydžiui (atitinkamai $d = -1{,}45$ ir $-1{,}05$). Kadangi technologijos yra dinamiškos ir sudėtingos, mokytojams reikia nemažai laiko, kad įgytų technologinį meistriškumą. Tyrime rekomenduojama rengti poreikiais grindžiamas TPD programas, siekiant pagerinti mokytojų TPACK, ypač technologijų žinias.

Esminiai žodžiai: *biologijos mokymas, neturintys pedagoginio išsilavinimo mokytojai, mokytojų profesinis tobulėjimas, technologinės žinios, TPACK.*

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