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Pre-Service Teachers' Attitudes Toward ICT, TPACK Acquisition, and Readiness in Fostering Education for Sustainable Development

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Abstract. This research assessed the attitudes toward ICT, TPACK† acquisition, and readiness of the 95 fourth-year pre-service teachers taking up Bachelor of Early Childhood Education and Bachelor of Elementary Education degrees in fostering Education for Sustainable Development (ESD) at Cebu Technological University Main campus for the school year 2023-2024 using a descriptive correlational design. The respondents were identified using a census sampling technique due to the small population and were asked to answer the three-part survey questionnaires. The data gathered was treated using appropriate descriptive and inferential statistics. The results revealed that the respondents had very positive attitudes toward ICT integration in education. At the same time, they highly acquired the four dimensions of TPACK technology and were extremely ready to foster ESD. Furthermore, significant relationships were found between the attitudes toward ICT and TPACK acquisition, and readiness in fostering ESD. There was also a significant relationship between TPACK acquisition and readiness in fostering ESD. The study demonstrated that the pre-service teachers are well-equipped with strong technological competencies and commitment to promoting sustainability in early childhood education which are linked to their readiness in implementing ESD. Such findings underscore the importance of integrating technology and sustainability training in teacher education programs to prepare future teachers in fostering sustainability awareness among young learners. Hence, it is recommended that the curricula be improved to integrate ICT and ESD concepts through the enhanced practical ICT use experiences.

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† TPACK stands for Technological Pedagogical Content Knowledge and represents the intersection of all three knowledge areas: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK)

Keywords: Information and Communication Technology; Technological Pedagogical Content Knowledge; Education for Sustainable Development; Pre-service Teachers

1. Introduction

In today's rapidly evolving global landscape, technology has become an indispensable part of daily life. It influences how people communicate, learn, and solve problems. Particularly, the integration of Information and Communication Technology (ICT) in education has become increasingly imperative (Chansanam et al., 2021; Mavuso & Makeleni, 2022; Naidoo, 2020; Rahimi & Oh, 2024; Sibagariang et al., 2023). The digital age demands educators proficient in traditional teaching methods and adept at leveraging technology to enhance teaching and learning experiences (Tran et al., 2020). Simultaneously, there is a growing recognition of the importance of Education for Sustainable Development (ESD) in preparing students to address complex environmental, social, and economic challenges (Price et al., 2021).

In response to these global imperatives, the Philippines, like many other nations, strives to equip teachers with the necessary skills and competencies to navigate this dynamic educational landscape effectively (Barnes et al., 2023). As the nation endeavors to enhance its educational system to cope with the demands of the twenty-first century, it is essential to ensure that future educators are equipped with the knowledge, skills, and attitudes necessary to leverage technology effectively and promote sustainable development (González-Salamanca et al., 2020). However, while efforts have been made to integrate ICT and ESD into teacher education programs, there remains a gap in research regarding pre-service teachers' attitudes toward these critical domains.

In the landscape of teacher education in the Philippines, there is a notable lack of emphasis on incorporating Technological Pedagogical Content Knowledge (TPACK) and ICT capability training for university pre-service teachers (Marcos, 2025). Despite the increasing importance of technology in education and the demands of the modern teaching profession, many teacher education programs in the Philippines still do not adequately prioritize the development of TPACK and ICT competencies among their pre-service teachers (Gonzales & Gonzales, 2021). One of the primary reasons for this lack of emphasis is the traditional nature of many teacher education curricula, which may be slow to adapt to rapid technological advancements (Kımav & Aydın, 2020). Historically, teacher education programs in the Philippines have focused more on pedagogical theory and subject-specific content knowledge, often overlooking technology integration into teaching practices (Relator, 2022). As a result, pre-service teachers may graduate with insufficient skills to effectively use technology in their future classrooms.

Furthermore, limited resources and infrastructure within universities may also hinder the integration of TPACK and ICT capability training into teacher education programs. Some universities in the Philippines lack access to up-to-date technology resources, such as computers, software, and internet

connectivity, essential for providing hands-on training in ICT integration (Lira & Pascua, 2023; Morales et al., 2021). Without adequate resources and support, it becomes challenging for teacher education programs to incorporate TPACK and ICT training into their curricula effectively (Koh, 2019; Ngao et al., 2022; Syamdianita & Cahyono, 2021). Due to these shortcomings, pre-service teachers in the Philippines may enter the profession without being fully equipped with the skills and knowledge needed to navigate the digital education age. In this time where technology has been more integrated in teaching and learning, this lack of preparation can put pre-service teachers at a disadvantage and hinder their ability to meet the diverse needs of twenty-first-century learners (Hong & Ling, 2018; Vistari, 2023).

Hence, TPACK and ICT competency training should be encouraged to be incorporated into Philippine teacher education programs' curricula. Therefore, by giving pre-service teachers the skills and competencies which are important in using technology to improve their teaching practices, colleges may better prepare them for the new trends in classroom instruction (Dzinoreva & Mavunga, 2022). Furthermore, pre-service teachers can be encouraged to accept technology as a useful instrument for fostering educational achievement in the digital era by receiving sufficient resources and support for TPACK and ICT training.

More importantly, introducing technology in the early years of education, particularly in preschool and primary schools, is widely recognized as beneficial for several reasons. Pre-service teachers who specialize in early childhood and primary education must possess the abilities and knowledge necessary to successfully use technology into their teaching methods, considering the significance of this field (Mertala, 2019). This includes understanding how to select and use age-appropriate educational technology tools, designing engaging and interactive learning experiences, and incorporating technology into curriculum planning and assessment practices. This principle has been adopted by Cebu Technological University (CTU), a state university in Cebu, Philippines, by integrating ICT and TPACK training in the curriculum for pre-service teachers taking up Bachelor of Early Childhood Education (BECED) and Bachelor of Elementary Education (BEED). However, there has been no assessment on the ICT skills and TPACK acquisition of the pre-service teachers before they graduate to check if the curriculum meets the goals of the program.

Given the aforementioned scenario, the researchers were motivated to assess the fourth-year pre-service teachers' attitudes toward ICT integration, TPACK acquisition, and readiness for ESD who are taking up BECED and BEED at CTU main campus. Specifically, it sought answers to the following queries:

1. What is the level of the respondents' attitudes toward ICT integration in education?
2. What is the level of the respondent's acquisition of the TPACK technology dimensions?
3. What is the level of the respondents' readiness in fostering ESD?
4. Is there a significant relationship between the:

4.1 respondents' attitudes toward ICT integration in education and acquisition of the TPACK technology dimensions,
4.2 respondents' acquisition of the TPACK technology dimensions and readiness in fostering ESD,
4.3 Respondents' attitudes toward ICT integration in education and readiness in fostering ESD?

2. Materials and Methods

2.1 Research Design

This research used a descriptive correlational research design to test the relationship between pre-service teachers' attitudes toward ICT, TPACK acquisition, and readiness in fostering ESD. Correlational research is a type of research that tests the relationship between two variables without controlling any of these variables (Bhandari, 2023). Moreover, this study used survey questionnaires to gather the pre-service teachers' attitudes toward ICT, TPACK acquisition, and reading in fostering ESD.

2.2 Research Participants

The study purposively selected the fourth-year BECED and BEED pre-service teachers of CTU Main campus as the respondents. The distribution is shown in Table 1.

Table 1. Distribution of the Respondents

Course	n	%
BECED	44	46.32
BEED	51	53.68
Total	**95**	**100.00**

The study used the complete enumeration (census sampling) technique to determine its respondents due to the small population. These respondents were appropriate to answer the questionnaires of this study because the university has already trained them on the basic teaching principles they can apply in their profession. Moreover, the fourth-year pre-service teachers have already been exposed to practice teaching based on the required number of hours set by the Commission on Higher Education. Hence, these experiences can help them evaluate their readiness for teaching. Lastly, these respondents were of great help in providing important information about the variables that were measured in this study.

2.3 Data Collection Tools

This research used three sets of survey questionnaires that the pre-service teachers answered to gather the needed information to meet the study's objectives. Part I used a survey questionnaire comprising statements describing the pre-service teachers' attitudes toward ICT, which was adopted from Oparah et al. (2017). It has 20 statements in which the respondents were asked to rate themselves on how they feel and think about integrating ICT into education. The questionnaire has a five-point Likert scale: 5-Strongly Agree, 4-Agree, 3-Undecided, 2-Disagree, and 1-Strongly Disagree. The instrument was subjected to face validity by two educators and experts whose suggestions were the basis for restructuring the instrument. Moreover, a test-retest method was used to

check the reliability of the instrument which achieved an acceptable reliability coefficient value (r=0.76). Part II used a questionnaire containing statements that described the TPACK acquisition of the pre-service teachers. The instrument was adapted by Tondeur et al. (2017) from the Dutch version of Schmidt et al.'s (2009) TPACK self-report scale. The revised instrument was subjected to reliability test using Cronbach's alpha for the general TPACK (TPCK, TPK, and TCK) and specific TK factor with values of α =0.94 and α =0.89, respectively, indicating a high internal consistency of the statements measuring the construct (Taber, 2018). The pre-service teachers were asked to rate themselves as to their self-assessment on their acquisition of these skills using the five-point Likert scale, namely: 5-Strongly Agree, 4-Agree, 3-Undecided, 2-Disagree, and 1-Strongly Disagree. Part III used a questionnaire containing statements describing the pre-service teachers' readiness to foster ESD, which was adopted from Manasia et al. (2019). The instrument development underwent the three-stage process such as the literature review, pretesting using factor analysis, and development of the final version to ensure its validity.

Moreover, Cronbach's alpha was used to test its reliability. The alpha coefficient obtained for the overall construct was 0.973 while for each dimension such as Professional knowledge (α=0.884), Professional practice (α=0.939), Professional engagement (α=0.925), and Self-management (α=0.882) indicating a very good scale reliability. The pre-service teachers were asked to rate themselves as to their self-assessment on their readiness of these skills using the five-point Likert scale, namely: 5-Strongly Agree, 4-Agree, 3-Undecided, 2-Disagree, and 1-Strongly Disagree.

2.4 Data Collection Process

The researchers observed the proper protocol during the conduct of the study based on the CTU policy specifically on the observance of the ethical considerations and Data Privacy Act to protect the rights of the participants of the study. A letter was sent to the dean of the College of Education of CTU to ask permission to conduct the study. After the letter was approved, the researcher informed the respective professors of the students about the intent to conduct the study and arranged the schedule for the study with them.

During the set schedule, the researchers met the pre-service teachers involved and asked for their consent to participate in the study. They were informed of their right at any time when they no longer feel comfortable with the process. When everything was set, the respondents were given a brief orientation on their roles in the study. Instructions were given on how to answer the questionnaires. Assistance was provided to them while they were answering the questionnaires. They were given enough time to answer the questionnaires. Retrieval of the questionnaires followed. A brief interview was conducted with the selected respondents on the relevant information of the study to validate their answers to the questionnaires. The data gathered from the respondents were kept confidential and stored correctly.

2.5 Data Analysis

After gathering data from the respondents, these data were organized, summarized, tallied, interpreted, and analyzed according to the study's objectives. Appropriate statistical tools were used in treating the quantitative facts and information to provide valid and reliable results for the study. Weighted mean was used to determine the pre-service teachers' attitudes toward ICT, TPACK acquisition, and readiness in fostering ESD. Standard Deviation was used to measure the spread of the respondents' answers to every statement, measuring the variables investigated. Pearson's r was used to test the significance of the relationship between the pre-service teachers' attitudes toward ICT, TPACK acquisition, and readiness in fostering ESD. Moreover, the study tested the following null hypotheses:

Ho_1: There is no significant relationship between the respondents' attitudes toward ICT integration in education and the acquisition of the TPACK technology dimensions.

Ho_2: There is no significant relationship between the respondents' acquisition of the TPACK technology dimensions and readiness to foster ESD.

Ho_3: There is no significant relationship between the respondents' attitudes toward ICT integration in education and readiness to foster ESD.

3. Results

Through the respondents' answers to questionnaires administered to them, the results and findings of this study are presented and discussed in this section which includes the respondents' attitudes toward ICT integration, TPACK acquisition, readiness in fostering ESD, and the relationship of these variables.

3.1 Level of the respondents' attitudes toward ICT integration in education

First, the section presents the respondents' attitudes toward ICT integration in education. As pre-service teachers, they have used ICT integration in teaching. The respondents' assessment of ICT integration in teaching can provide significant inputs on enhancing the teacher's strategies in teaching early-grade learners. Table 2 shows that the aggregate weighted mean for the respondents' attitudes toward ICT integration in education is 4.50, with an aggregate standard deviation of 0.55, signifying that they have very positive attitudes toward ICT integration.

Table 2. Level of the respondents' attitudes toward ICT integration in education

S/N	Indicators	WM	SD	Verbal Description
1	Lecture with ICT tool is interesting.	4.64	0.48	Very Positive
2	Use of ICT tools improves learning.	4.72	0.45	Very Positive
3	ICTs in the classroom make teaching and learning lively.	4.64	0.50	Very Positive
4	It is easy to learn with ICTs.	4.40	0.63	Very Positive
5	ICT tools enable access to learning materials.	4.66	0.48	Very Positive
6	ICTs enable access to innovations in teaching and learning.	4.66	0.48	Very Positive
7	ICTs create an effective learning atmosphere.	4.53	0.60	Very Positive

S/N	Indicators	WM	SD	Verbal Description
8	ICTs enable access to materials for assignments.	4.59	0.54	Very Positive
9	I like attending classes when ICT tools are used.	4.35	0.60	Very Positive
10	ICTs help me organize my work.	4.56	0.52	Very Positive
11	I understand more when ICT is used in the classroom.	4.39	0.55	Very Positive
12	ICT allows me to share ideas with others within and outside the classroom.	4.55	0.52	Very Positive
13	I enjoy learning with ICT tools.	4.48	0.56	Very Positive
14	Use of ICTs in learning gives flexibility to learning.	4.54	0.52	Very Positive
15	Use of ICTs in classroom enable me have immediate feedback.	4.45	0.54	Very Positive
16	Using ICTs in classroom learning makes me confident.	4.37	0.55	Very Positive
17	ICTs enable a variety of solutions to problem situations.	4.39	0.59	Very Positive
18	Use of ICT motivates me to study outside classroom.	4.34	0.68	Very Positive
19	I gain sufficient knowledge in class when ICTs are used.	4.43	0.58	Very Positive
20	I prefer ICTs in teaching and learning than traditional approach.	4.32	0.62	Very Positive
	Aggregate Weighted Mean	**4.50**		**Very Positive**
	Aggregate Standard Deviation		**0.55**	

Legend: 4.21-5.00-Very Positive; 3.41-4.20-Positive; 2.61-3.40-Neutral; 1.81-2.60-Negative; 1.00-1.80-Very Negative

3.2 Level of the respondent's acquisition of the TPACK technology dimensions

Table 3 presents the level of the respondent's acquisition of the TPACK technology dimensions, which are essential in the development of the teaching strategies of future teachers while integrating technology into their teaching practices. The results revealed the respondents highly acquired the TPACK technology dimensions in terms of TCK(WM=4.42,SD=0.53), TPK(WM=4.44,SD=0.52), TPCK(WM=4.44,SD=0.52), and TK(WM=4.30,SD=0.61). In general, the respondents had highly acquired TPACK with a grand mean of 4.40 and 0.55 grand standard deviation.

Table 3. Level of the respondent's acquisition of the TPACK

Components	WM	SD	Verbal Description
Technological Content Knowledge	4.42	0.53	Highly Acquired
Technological Pedagogical Knowledge	4.44	0.52	Highly Acquired
Technological Pedagogical Content Knowledge	4.44	0.52	Highly Acquired
Technological Knowledge	4.30	0.61	Highly Acquired
Grand Mean	**4.40**		**Highly Acquired**
Grand Standard Deviation		**0.55**	

Legend: 4.21-5.00-Highly Acquired; 3.41-4.20- Acquired; 2.61-3.40- Moderately Acquired; 1.81-2.60-Less Acquired ; 1.00-1.80-Not Acquired

3.3 Level of the respondents' readiness in fostering ESD

Table 4 presents the respondents' level of readiness to foster ESD. As future teachers, it is important that the pre-service are equipped with sufficient knowledge and skills in fostering ESD to help promote the United Nations sustainable development goals. It is reflected in the table that the pre-service teachers are extremely ready in all the components of fostering ESD such as Professional Knowledge (WM=4.31, SD=0.55), Professional Practice (WM=4.43, SD=0.54), Professional Engagement (WM=4.55, SD=0.56), and Self-Management (WM=4.55, SD=0.53). More importantly, the pre-service teachers' readiness level in fostering ESD has a grand mean of 4.45 and 0.55 standard deviation, indicating that the pre-service teachers are extremely ready to foster ESD.

Table 4. Level of the respondents' readiness in fostering ESD

Components	WM	SD	Verbal Description
Professional Knowledge	4.31	0.55	Extremely Ready
Professional Practice	4.43	0.54	Extremely Ready
Professional Engagement	4.51	0.56	Extremely Ready
Self-Management	4.55	0.53	Extremely Ready
Grand Mean	**4.45**		**Extremely Ready**
Grand Standard Deviation		**0.55**	

Legend: 4.21-5.00-Extremely Ready; 3.41-4.20- Ready; 2.61-3.40- Moderately Ready; 1.81-2.60-Less Ready; 1.00-1.80-Not Ready

3.4 Relationship of the variables investigated

Table 5 revealed a strong positive correlation between ATICT and TPACKA ($r=0.766$, $p<0.001$), TPACKA and RFESD ($r=0.772$,$p<0.001$) while a moderate positive correlation between ATICT and RFESD ($r=0.598$,$p<0.001$). These results indicate significant relationship between these variables.

Table 5. Correlation analysis

		1	2	3
1	ATICT	1		
2	TPACKA	0.766***	1	
3	RFESD	0.598***	0.772***	1

Legend: ATICT=Attitudes toward ICT; TPACKA=TPACK Acquisition; RFESD=Readiness in Fostering ESD
***significant at $p<0.001$

4. Discussion

The results of this study provide significant insights in understanding the pre-service teachers' attitudes toward ICT, TPACK acquisition, and readiness in fostering ESD together with the interplay of these variables. This section presents the findings based on the data gathered from questionnaires used in this study.

4.1 Respondents' attitudes toward ICT integration in education

The data gathered on the pre-service teachers' attitudes toward ICT showed a positive outlook toward ICT tools. They believe using ICT in classroom instruction improves learning and makes the lessons more engaging. Moreover, the very positive attitudes of the pre-service teachers toward ICT integration

provide significant insights into the future of education in the Philippines, which is slowly adapting to technology in teaching. The pre-service teachers' positive disposition shows that they are willing to embrace technology in their teaching and are also open to using it effectively in their future teaching endeavors, which demonstrates that these future educators appreciate the importance of technology in improving learning outcomes and introducing innovative teaching methods (Seufert et al., 2021).

Furthermore, the results are important bases in enhancing the training to pre-service teachers in TPACK and making ICT resources available to them to address the educational challenges. Furthermore, the university must prioritize developing the ICT skills integrated into the curriculum to ensure that future educators may gain enough expertise in their field and understanding of the role of technology in education (Akour & Alenezi, 2022). Previous research aligns with the current findings indicating favorable views of teachers toward ICT use in the classroom (Guillén-Gámez & Mayorga-Fernández, 2020; Ikwuka et al., 2020; Vuong, 2024).

4.2 Respondent's acquisition of the TPACK technology dimensions

It can be noted that the pre-service teachers highly acquired the TPACK technology dimensions in terms of TCK. Pre-service teachers' proficiency indicates their understanding of the digital tools and how to use them to enhance classroom learning experiences (Reisoğlu & Çebi, 2020). In early childhood education, teachers must simplify complex concepts and provide developmentally appropriate learning experiences that require them to apply technology to enhance young learners' engagement and understanding of basic skills such as literacy and numeracy (Falloon, 2020).

Moreover, TPK is important for teachers to ensure effective delivery of their lessons to learners in the digital age. Notably, the pre-service teachers have highly acquired these skills. The high extent of the pre-service teachers' TPK acquisition indicates that the teachers can effectively incorporate technology that supports young children's learning experiences, reinforcing the traditional teaching methodologies (Jita & Sintema, 2022). Likewise, integrating technology in early childhood learning can enhance learners' hands-on experiences with different manipulatives, which promotes active engagement (Sullivan & Strawhacker, 2021).

Another dimension of TPACK is TPCK which equips teachers with a sufficient understanding of the subject matter and pedagogy to deliver lessons to learners effectively. It can be seen in Table 3 that the pre-service teachers have highly acquired TPCK which suggests the high extent of pre-service teachers' readiness to integrate technology strategically for more effective delivery of the subject matter to the learners. TPCK allows the teachers to use differentiated instruction to address the diverse needs of the learners and meet the learners' individual needs (Cahyono et al., 2023) although in the Philippine context, most teachers have limited access to resources (Kilag et al., 2024). The pre-service teachers' substantial acquisition of TPCK enables them to use available technology that creates a content-driven learning environment by using appropriate teaching

strategies that promote active engagement. On the other hand, TK refers to the teachers' familiarity with the different technologies in educational settings. Table 3 reflects that the pre-service teachers have highly acquired TK which indicates that the pre-service teachers are well-equipped to use a wide range of digital platforms to facilitate students' engagement and learning aligned with their learning objectives. Technology integration allows children to explore and interact with the lessons that traditional teaching may not provide (Liu, 2011). In addition, teachers' TK can promote a learning environment that enhances the learners' skills, ensuring the learners' holistic development. TK also encourages teachers to embrace creative and innovative methods for engaging students during their lessons (Bizami et al., 2023).

The current findings are aligned with previous research showing the strong knowledge of pre-service and in-service teachers of TPACK technology (Absari et al., 2020; Koyuncuoglu, 2021; Santos & Castro, 2021). Moreover, the pre-service teachers' high acquisition of the TPACK can significantly influence their teaching effectiveness, especially in dealing with early-grade learners, because they can easily integrate technology into their lessons, which helps the learners grasp the concepts quickly and engage in the discussions actively (Amri et al., 2024). Teachers with high TPACK can use technology that promotes creative and interactive learning experiences because these can be incorporated into early childhood education's play and exploration teaching principle. Nonetheless, teachers with strong TPACK can design lessons that are adaptive to the learners' various learning styles, which foster inclusivity in learning (Saenen et al., 2024).

4.3 Respondents' readiness in fostering ESD

Fostering ESD is vital in preparing young learners to address different societal issues, including environmental, social, and economic issues. ESD emphasizes teaching learners how to think critically and act responsibly with their choices and disposition in life. The results in Table 4 illustrate that pre-service teachers' preparedness to integrate essential teaching practices that promote a positive learning environment suggests they possess a strong foundation to teach young learners effectively (Brown et al., 2021). The results imply that the pre-service teachers are well-prepared in terms of professionalism when handling young learners. This professional knowledge can be translated into the appropriate recognition of the importance of the effective classroom management strategies that promote a safe and inclusive learning environment. In addition, when equipped with professional knowledge, teachers can build confidence in creating a supportive learning environment that allows children to feel valued and empowered to express themselves freely (El Zaatari & Ibrahim, 2021).

Pre-service teachers' readiness to foster ESD through professional practice is an important characteristic they must acquire because such skills enable them to incorporate sustainability concepts in their teaching strategies. Pre-service teachers' readiness in terms of their professional practice signifies that they are well-prepared to apply their knowledge and skills to design creative, inclusive, and meaningful learning experiences for young learners (Tandika & Ndijuye, 2019). The high level of readiness of the pre-service teachers as professional engagement indicates that they are committed to dealing professionally with the

stakeholders, such as the parents and their colleagues. To promote teaching sustainability, pre-service teachers' self-awareness and proactive approach to ensuring professional growth are necessary in catching up with the new trends and practices in early childhood education. Lastly, effective communication with parents is important in ensuring effective collaboration with the parents while adhering to ethical standards (Drossman et al., 2021). In this context, the child's progress is well-monitored, and the teacher can promote a supportive learning environment beyond the classroom.

In addition, self-management is an essential competency that pre-service teachers need to acquire to be ready in fostering ESD. Table 4 indicates that the pre-service teachers are extremely ready in self-management which suggests that they can manage their responsibilities, emotions, and time effectively. A teacher who can manage the classroom well can create a nurturing and well-being-centered environment promotes holistic child development. Moreover, effective time management allows teachers to allocate adequate time for specific classroom activities incorporating sustainability practices without compromising the other essential aspects of the curriculum. Nevertheless, teachers need to be flexible because the learners' needs and learning environment can change quickly, thus allowing them to adapt to these changes and ensure optimum learning experiences (Valtonen et al., 2021).

It can be noted that self-management has the highest mean, indicating that the pre-service teachers have strong self-management skills, which enable them to integrate sustainability topics in their lessons. Using these skills to implement lessons integrating sustainability practices can help the learners understand sustainability concepts and develop habits that contribute to a more sustainable future. In addition, the pre-service teachers' PK reflects their foundation on understanding the principles and goals of ESD. This knowledge is important in early childhood education because it equips teachers to simplify complex sustainability concepts to make them understandable for young learners. Teachers equipped with sufficient PK can guide the learners in understanding the world around them and help cultivate their curiosity about making their environment sustainable (Martinez, 2022).

4.4 Relationship of ATICT, TPACKA, RFESD

The test of the relationship between the pre-service teachers' attitudes toward ICT and TPACK acquisition revealed a strong positive correlation which highlights the importance of attitudes in shaping the pre-service teachers' readiness to adopt and integrate technology into their pedagogy. Pre-service teachers with a favorable view of ICT have greater chances of embracing technology to enhance children's learning. In the context of early education, young learners are more curious and exploratory. Thus, using technology in instruction provides the learners with opportunities to be exposed to interactive and hands-on learning experiences (Shieh, 2012). Research has demonstrated that pre-service attitudes toward technology can significantly predict TPACK development. Specifically, the study of Marbán and Sintema (2021) indicates that favorable attitudes toward technology lead to more innovative and frequent use

of ICT in teaching. Moreover, favorable attitudes toward ICT predict enhanced TPACK levels and contribute to improved technology integration in educational settings (Pozas et al., 2022). However, the presence of negative attitudes toward ICT can hinder the development and integration of TPACK among pre-service teachers (Demirtaş & Mumcu, 2021).

There was also a significant strong positive relationship between the pre-service teachers' TPACK acquisition and readiness in fostering ESD. The results indicate that as pre-service teachers acquire higher TPACK technology skills, their readiness to implement ESD increases significantly. When pre-service teachers have strong technological skills, they show readiness in integrating these concepts into the learning experiences of young learners. Moreover, the strong positive correlation also implies that pre-service teachers who are well-versed in using technology can incorporate strategies aligned with ESD. For early education teachers, it indicates that they can integrate activities that promote interaction and engagement.

Furthermore, acquiring TPACK technology dimensions allows teachers to fit in their teaching strategies to meet the needs of diverse learners (Jen et al., 2016). Durdu and Dag (2017) supported this study's findings, which found that acquiring TPACK leads to increased confidence and competence in using technology to address sustainability issues. Programs that integrate TPACK training within the curriculum enhance teachers' technological skills and promote their readiness to implement ESD effectively. Such programs help develop pedagogical strategies that merge technology with sustainability education (Chaipidech et al., 2021; Kaplon-Schilis & Lyublinskaya, 2020). Then again, Yurdakul (2017) found that digital literacy is a significant predictor of TPACK competency in pre-service teachers.

Lastly, the relationship between the respondents' attitudes toward ICT integration in education and their readiness to foster ESD was found to be significantly moderate positive. The results affirmed the importance of ICT in the innovation of teaching practices, which aid in promoting sustainability because technology can offer an interactive and engaging learning environment. The positive attitudes of pre-service teachers toward ICT enable them to use digital technology in the classroom by providing learners with age-appropriate activities.

Previous studies supported these results, which found that positive attitudes toward ICT contribute to the pre-service teachers' readiness to integrate ESD into teaching practices (Manasia et al., 2019; Peng et al., 2023; Pozas & Letzel, 2021). Hence, integrating ICT and ESD principles within teacher training programs can enhance future educators' self-efficacy and readiness to implement innovative teaching strategies. Programs that foster a positive attitude toward ICT can empower pre-service teachers in their roles as agents of change for sustainable development (Manasia et al., 2019).

5. Conclusion

This study aimed to assess the pre-service teachers' attitudes toward ICT, TPACK acquisition, and readiness in fostering ESD. It also tested the relationship of these variables. Interestingly, the study's findings highlight the integral role of technology in preparing the pre-service teachers in fostering ESD. The pre-service teacher's positive outlook toward ICT integration in education reflects their openness in embracing the ICT tools in their teaching practices. This positive orientation toward technology is important in ensuring an interactive learning environment for young learners. Moreover, the respondents strongly believe in their high level of acquisition of the TPACK dimensions, which are crucial in their teaching profession.

This belief suggests that they have the competencies in integrating technology in teaching. Hence, they can effectively navigate the technology dimensions to ensure that ICT tools are not only supplementary but also embedded in their instructional strategies. The ability to integrate developmentally appropriate technologies is essential in young learners because this can promote foundational learning experiences where abstract concepts become tangible for learners. In addition, the pre-service teachers are highly prepared to promote ESD through their professional knowledge, practice, engagement, and self-management skills.

The findings further suggest that cultivating positive attitudes toward ICT enhances their technological proficiency and equips them with essential skills necessary for promoting sustainable educational practices. In the early-grade classrooms, this means creating a classroom atmosphere that is more interactive and engaging in technology to promote critical thinking, environmental awareness, and social responsibility. Nevertheless, although the pre-service teacher's preparedness is promising, continuous training and practical experience are important to ensure that these skills transfer to actual classroom teaching. Moreover, by combining technology and sustainability in the teaching practices, the future teachers can influence young learners to be both digitally skilled and environmentally aware, equipping them to make a valuable contribution to sustainable future.

However, the study has some limitations which limits the generalizability of its findings in other contexts such as the small sample size due to the small population of the respondents, the scope of the study focused only in one university which limits the respondents' perspective only in the university's context, and use of self-report measures which may compromise the objectivity of the findings.

6. Recommendation

Based on the study's findings, it is recommended that teacher education programs improve their curricula to better incorporate ICT and ESD concepts. This can be accomplished by offering pre-service teachers' additional opportunities for practical experience in using technology to teach sustainability ideas, especially to young learners. The enhancement of TPACK will empower

upcoming educators to seamlessly integrate subject content, teaching strategies, and technology. Moreover, cultivating favorable perceptions of ICT integration can improve pre-service teacher's preparedness on teaching ESD, ultimately aiding young learners by providing them with skills and knowledge essential for a sustainable future. However, such recommendations are limited to study's findings. Hence, future researchers may use other data sources and longitudinal studies to validate the current findings and provide more insightful recommendations.

7. References

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