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Technological Integration Self Efficacy (TISE) of Prospective Mathematics Teacher Students through TPACK Implementation

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ABSTRAK

Kepercayaan diri yang tinggi dalam mengintegrasikan teknologi dalam pembelajaran merupakan salah satu aspek penting yang relevan dengan TPACK. Penelitian ini bertujuan untuk menganalisis Technological Integration Self Efficacy (TISE) mahasiswa calon guru melalui implementasi TPACK. Penelitian ini menggunakan metode Didactical Design Research (DDR) yang terdiri dari tiga tahap, yaitu: analisis prospektif yang menghasilkan desain TPACK (HLT) analisis metapedadidaktif, menghasilkan implementasi TPACK, yang terdiri dari tahap pilot experiment dan teaching experiment; analisis retrospektif (restrospective analysis). Partisipan penelitian adalah mahasiswa calon guru matematika sebanyak 61 orang. Pada tahap Prospektif sebanyak 23 partisipan, tahap pilot experiment sebanyak 8 orang, dan tahap teaching experiment sebanyak 30 orang. Berdasarkan hasil penelitian, tingkat TISE mahasiswa calon guru berada pada kategori sedang, kemampuan TPACK mempengaruhi skor TISE. Pengetahuan siswa terhadap TIK, sangat menunjang TISE mahasiswa dalam menguasai TIK. Mahasiswa yang memiliki pengetahuan TIK yang baik, pada umumnya memberikan respon yang sesuai dengan prediksi, begitupun sebaliknya, pengetahuan TIK yang lemah, memperlambat proses asimilasi dan akomodasi siswa dalam mengintegrasikan teknologi. Simpulan penelitian menunjukkan mahasiswa calon guru harus memiliki TISE sehingga dapat menyajikan pembelajaran yang lebih bermakna. Peningkatan TPACK pada skor TPACK guru tergantung pada lingkungan belajar untuk meningkatkan kompetensi dalam mengintegrasikan teknologi.

ABSTRACT

High self-confidence in integrating technology into learning is one of the critical aspects relevant to TPACK. This study aims to analyze prospective teacher students' Technological Integration self-efficacy (TISE) through implementing TPACK. This study uses the Didactic Design Research (DDR) method, which consists of three stages: prospective analysis that produces TPACK design (HLT) metapedadactive analysis, producing TPACK implementation, consisting of the pilot experiment and teaching experiment stages, and retrospective study. The research participants were 61 prospective mathematics teacher students. In the Prospective stage, there were 23 participants; in the pilot experiment stage, there were 8 people; and in the teaching experiment stage, there were 30 people. Based on the study results, the TISE level of prospective teacher students is in the moderate category, TPACK ability affects the TISE score. Students' knowledge of ICT greatly supports students' TISE in mastering ICT. Students with good ICT knowledge generally provide responses that are by predictions, and vice versa; weak ICT knowledge slows down the assimilation and accommodation of students in integrating technology. The study's conclusion shows that prospective teacher students must have TISE to present more meaningful learning. The increase in TPACK on teacher TPACK scores depends on the learning environment to improve competence in integrating technology.

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1. INTRODUCTION

Mathematics learning should not only emphasize cognitive aspects, but should also pay attention to other student potentials such as emotional aspects and physical skills. According to Bloom, learning outcomes include cognitive, affective, and psychomotor domains (Nirwana et al., 2021; Oktafiona et al., 2022). Mathematics not only involves logical thinking, but is also influenced by affective aspects (Hannula, 2014). Therefore, the affective aspect also plays an important role in learning mathematics. Affective and cognitive aspects different but interrelated in mental representation interact dynamically with each other, so that learning outcomes in the cognitive domain can influenced by affective aspects (Jeon, 2017). The role of affective in mathematics education shows that affective aspects affect students' performance in solving non-routine problems. Studies on the affective dimensions of mathematics learning have been conducted for decades, shown in the initial focus only on students' attitudes towards mathematics, over time attention to the affective domain has increased (Mujib & Mardiyah, 2017; Wiguna et al., 2022). The affective domain involves attitudes, beliefs, motivations, emotions, and all non-cognitive elements of the human mind (Hannula, 2004). Self-efficacy is one of the affective domains related to beliefs. This self-efficacy has a relationship with ICT.

Current technological developments are experiencing very significant acceleration.The era of the Covid-19 pandemic has changed the direction of education in Indonesia, especially in the field of education and learning (Heru et al., 2021; Yuliani & Heru, 2021). Effectively integrating ICT into learning is an essential competency for teachers in the 21st century. Teachers who master digital technologies can use technology to improve teaching efficiency, facilitate meaningful learning, and help students build real-world knowledge (Zhang et al., 2023). The acceleration of the development of this innovation has a significant impact on the management of learning activities. Therefore, prospective teacher students are required not only to have good teaching skills and knowledge related to learning content, but also skills in utilizing and integrating ICT in learning. One form of ICT integration in learning, especially Mathematics lessons, isTechnological Pedagogical and Content Knowledge(TPACK). TPACK is knowledge about teachers' abilities in integrating technology based on material character analysis and pedagogical aspect analysis (Kiray, 2016; Mishra, 2019; Schmidt et al., 2009). Integrating ICT into classroom learning is a challenge that is not easy to face (Oktalia & Drajati, 2018; Rosyd, 2016). On average across countries, less than half of teachers report frequent use of ICT when teaching, and almost two-thirds of teachers have inadequate ICT skills. (Fraillon et al., 2020). The integration of ICT in the teaching environment in mathematics classes seems to remain far from initial expectations (Marban & Mulenga, 2019). A more problematic and worrying issue is that prospective teachers also have difficulty integrating technology (Farjon et al., 2019). Several studies have shown that prospective and beginning teachers are not adequately integrating technology into their educational practices (Tondeur et al., 2012, Tounder et al., 2016). There is a gap between what is taught to prospective teachers and the reality of classroom learning in terms of the use of technology in their practical activities. In addition, novice teachers indicated that they did not feel fully prepared to integrate technology in the classroom (Admiraal et al., 2013; Tondeur et al., 2017). This will have an impact on the less than optimal preparation of prospective teachers in integrating effective technology.

Previous findings suggest that preservice teachers' TPACK has been explored in relation to internal factors that facilitate or constrain their use of ICT in the classroom. Two factors hinder preservice teachers and teachers in effective use of technology, namely internal factors (e.g., constructivist beliefs, attitudes towards teaching, ICT self-efficacy, learning strategies) and external factors (e.g., access to ICT equipment, institutional support) (Tondeur et al., 2019; Yeh et al., 2017; Zhang et al., 2023). Barriers related to internal factors are often more critical than external barriers, because they are implicit and less observable (Zhang et al., 2023). Internal factors such as teacher attitudes are strong determinants in integrating technology into learning (Scherer et al., 2018). Self efficacyteachers in the use of technology as an internal barrier that affects technological competence (Birisci & Kul, 2019; Jason T. Abbitt, 2011). Bandura's theory of self-efficacy states that by increasing teacher knowledge, it will increase self-efficacy and the potential for increased use of technology in the classroom, especially in the context of content knowledge and pedagogy (Jason T. Abbitt, 2011). Confidence in integrating technology is known as Technology Integration Self Efficacy (TISE). TISE is considered an important factor in a teacher's decision to use technology in the classroom (Wang et al., 2004). In Bandura's theory of self-efficacy, increasing teacher knowledge can increase self-efficacy beliefs and the potential for increased use of technology in the classroom, especially in the context of content knowledge and pedagogy (Jason T. Abbitt, 2011). Therefore, this study aims to analyze the Technological Integration Self Efficacy (TISE) of prospective teacher students through the implementation of TPACK.

2. METHOD

This research uses qualitative research methods, namelydesign researchwith the perspective of didactic situation theory (theory of didactical situation) which is known by the term Didactic Design Research (DDR). DDR was introduced as a model of educational research in Indonesia by Suryadi (2013). This study includes three stages, namely: Prospective Analysis to produce TPACK (HLT) design; Meta pedadidactive analysis to implement TPACK, consisting of the pilot experiment and teaching experiment stages; Retrospective analysis that connects the results of the Prospective analysis with the results of the metapedadidactive analysis. A total of 61 prospective mathematics teacher students participated in this study, with a different number of participants at each stage, namely 23 participants at the Prospective, 8 people at the stage pilot experiment, and 30 people at the stage teaching experiment.The instruments used in this study were the TISE Questionnaire, interviews, observations, documentation, and videos. The TISE questionnaire instrument used was the TISE instrument developed by Kiili et al.(2016)consists of a set of instruments that have been tested for validity and reliability on an international scale. The questionnaire contains 14 statement items. The TISE questionnaire can be seen in Table 1.

Table1. The Technological Integration Self Efficacy Questionnaire Instrument(Kiili et al., 2016)

Components of self-efficacy	Item No	Statement	Scale
Computer self-efficacy	1	I feel confident that I can use ICT efficiently.	1-4
	2	I feel confident that I can learn to use new ICT tools independently.	1-4
	3	I feel confident that when I use ICT I can solve technical problems if I encounter them.	1-4
	4	I feel confident that I can find useful ICT applications on the Internet if I need them.	1-4
	5	I feel confident that I can download programs on the Internet.	1-4
Teacher self-efficacy	6	I feel confident that I can apply different types of teaching methods to enhance my students' learning later.	1-4
	7	I feel confident that I can create meaningful learning experiences for my students.	1-4
	8	I feel confident that I can motivate my students to be actively involved in their learning.	1-4
	9	I feel confident that I can develop my teaching	1-4
Self-efficacy towards technology integration	10	I feel confident that I can integrate ICT as a meaningful part of my teaching.	1-4
	11	I feel confident that I can find new ways to apply ICT in my teaching.	1-4
	12	I feel confident that I can motivate students to use ICT in their learning.	1-4
	13	I feel confident that I can create meaningful learning experiences for my students with ICT.	1-4
	14	I feel confident that I can apply ICT to enhance my students' learning.	1-4

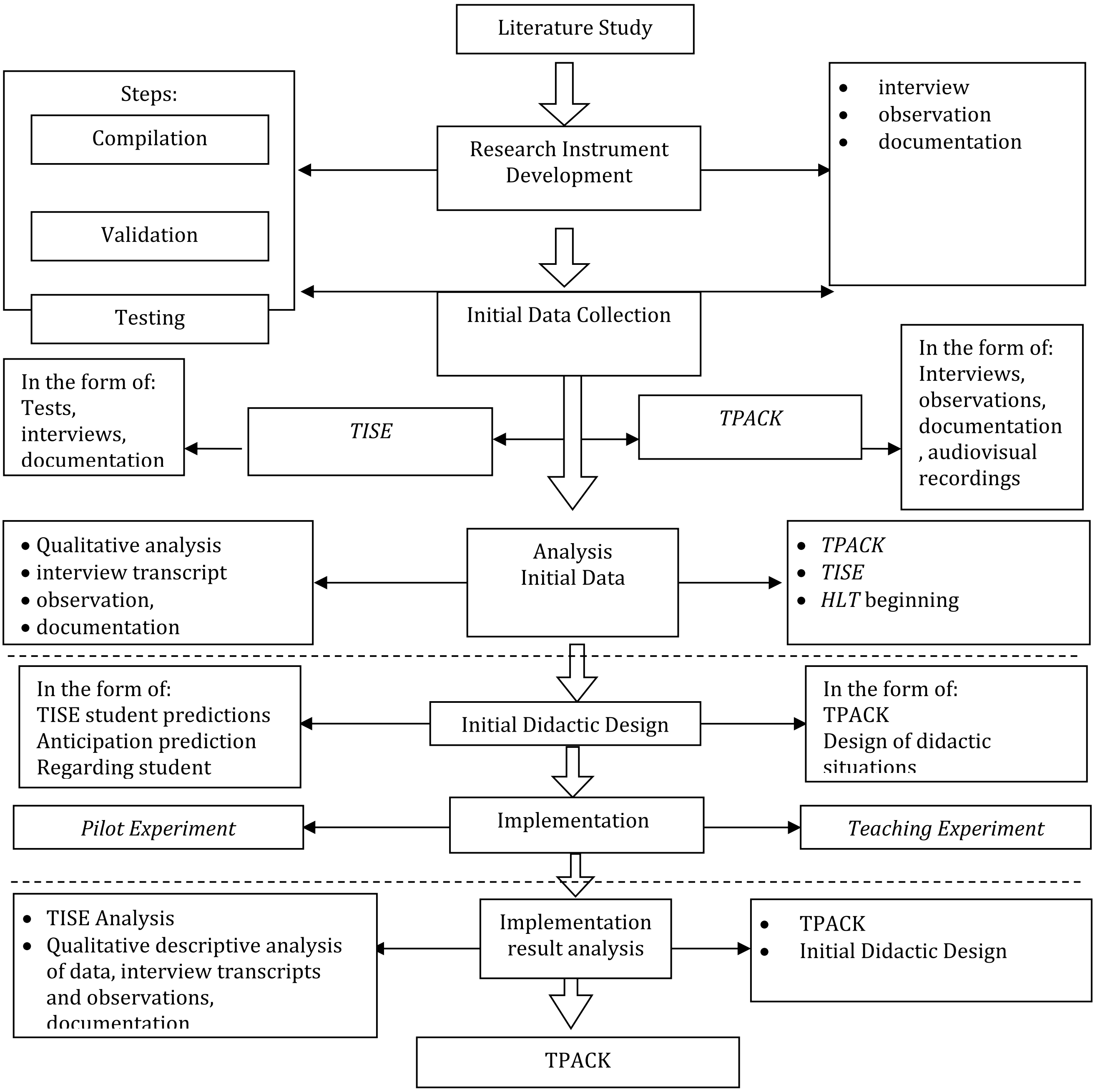

Figure 1. The Research Procedure Chart

3. RESULTS AND DISCUSSION

The prospective analysis stage is an analysis of the didactic situation before the implementation of TPACK. At this stage, the researcher conducted a literature study on Technological Integration Self Efficacy (TISE), Technological Pedagogical Content Knowledge (TPACK), self-efficacy, learning barriers, and alleged learning trajectories. Then, identification of TISE and learning barriers was carried out to produce a hypothetical didactic design (HLT) that included pedagogical didactic anticipation. At this stage, the researcher identified the TISE of 23 prospective mathematics teacher students, where more than 50% of them stated that they felt confident in integrating technology into mathematics learning. The metapedadidactic analysis stage, developed the initial didactic design of Technological Pedagogical Content Knowledge (TPACK), made predictions about student responses that might arise when the initial didactic design was implemented and prepared anticipation of student responses that emerged. At this stage, the researcher predicts the student responses that will emerge, including, students find it difficult to install the geogebra application, students are not familiar with the geogebra application, students cannot use the geogebra application, students cannot operate the geogebra application, students are discouraged, and various other predictions. Making anticipations that can be done to overcome self-efficacy barriers. Anticipation can change according to conditions in the field when implementing the didactic situation design. Based on existing predictions, researchers have made anticipations to overcome obstacles that may occur during the implementation of TPACK. Implementing the initial didactic design that has been prepared, At this stage the researcher implemented TPACK to 8 students. The implementation of TPACK uses various platforms, namely, Google Classroom, Zoom Meeting, Google Meet, and WhatsApp. Google Classroom used as the implementation of TPACK is presented in Figures 2 and Figure 3.

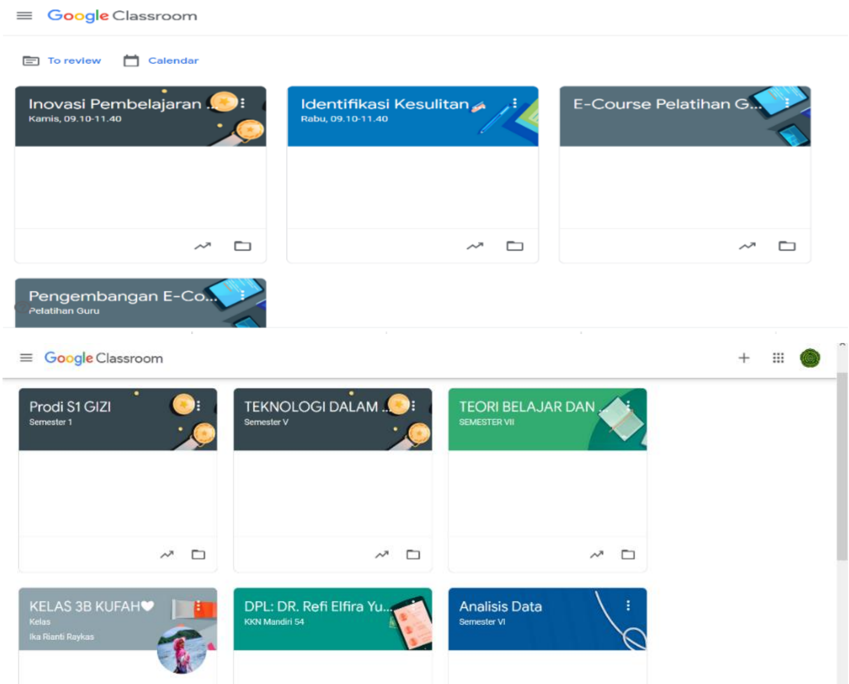

Figure 2. Google Classroom

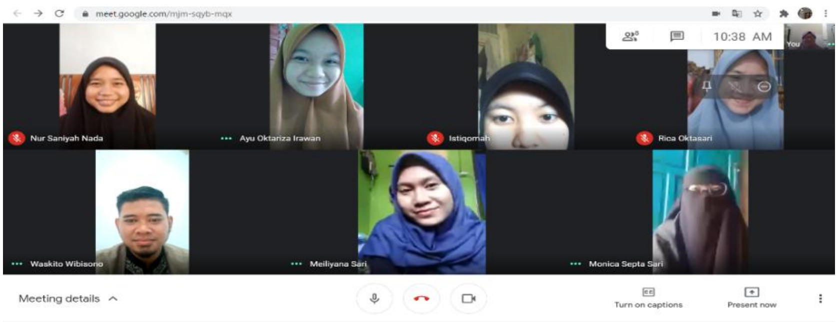

Figure 3. Participants in the Initial Implementation Using Google Meet

Based on the results of interviews with 8 students, they were able to understand the geogebra application quite well. Around 50% of students' TISE were in the medium interval. The main obstacle faced was poor signal constraints. In general, students live in areas far from the city center. This signal condition certainly makes it difficult for students in the lecture process, especially when installing the application being used. Likewise, during the TPACK implementation process, signal interference will affect information and knowledge transfer. To anticipate this obstacle, researchers optimized the use of Google Classroom, the material was re-posted on Google Classroom, so that students could study it again after the lecture schedule was completed. Analyze the situation from various responses when the initial didactic design was implemented. The implementation of the initial didactic design aims to explore, find out the strategies and thoughts of students in implementing Technological Pedagogical Content Knowledge (TPACK). Based on the initial implementation, the obstacle was the network problem which disrupted the information process and knowledge transfer. Based on the analysis of the situation and obstacles that occur, the solution for implementing TPACK is to use Google Classroom to re-post materials, conduct class discussions, reflect on TPACK implementation, and provide feedback on TPACK implementation.

The metapedadidactic analysis stage was carried out through initial experimental activities (Pilot Experiment) and teaching experiments (Teaching Experiment). The initial experiment (Pilot Experiment), the research participants in the initial experiment were 8 prospective mathematics teacher students who took the course on the use of technology in mathematics learning. The class was selected by purposive sampling with heterogeneous abilities. Learning in this class uses the didactic design of Technological Pedagogical Content Knowledge (TPACK) and initial HLT using the google classroom application. Teaching experiments (Teaching Experiment), the research participants were 30 students who took the Mathematics Learning Innovation course. After the implementation of TPACK, prospective mathematics teacher students were given the TISE questionnaire. The TISE Questionnaire was filled out online using google form. Based on the TISE conversion score, the TISE picture of prospective mathematics teacher students is known that the average TISE score is 77, the maximum value is 96, the minimum value is 61 and the standard deviation is 6.1. Based on the TISE category criteria, prospective mathematics teacher students are presented in Table 2.

Table 2. The TISE Category Prospective Teacher Students

TISE Category	TISE Score Intervals	TISE Score Intervals
Tall	$x \geq \bar{x} + sd$	$x \geq 83$
Currently	$\bar{x} - sd \leq x < \bar{x} + sd$	$71 \leq x < 83$
Low	$x < \bar{x} - sd$	$x < 71$

Arikunto(2012)

Based on Table 2, the student category has TISE in the high category if the score is , the medium value is in the interval 71-83, and the low category if the score is . Furthermore, based on the TISE category, the number of students in each category is presented in Table 3.$\geq 83 < 71$

Table 3. Number of participants in Each TISE category

TISE Category	TISE Score Intervals	Amount Participant	Percentage (%)
Tall	$x \geq 83$	4	13
Currently	$71 \leq x < 83$	23	77
Low	$x < 71$	3	10
Total		**30**	**100**

Based on Table 3, it is known that there are 4 students in the high category or 13%, 23 students in the medium category or 77%, and 3 students in the low category or 10%. The retrospective analysis stage is the analysis stage that connects the results of the implementation analysis with the results of the metapedadidactic analysis (Suryadi, 2013). The purpose of this stage is to evaluate the data that has been collected and see whether it is in accordance with the conjecture that has been designed or not. The data analyzed include photo documentation, video recordings of learning, results of interviews with students, field notes, and video and audio recordings that cover the research process from the beginning. The results of the analysis show that 84% of students are confident that they can use ICT efficiently. There are about 10% of students who are not confident that they can use ICT tools independently. TISE aspects showed in Figure 4.

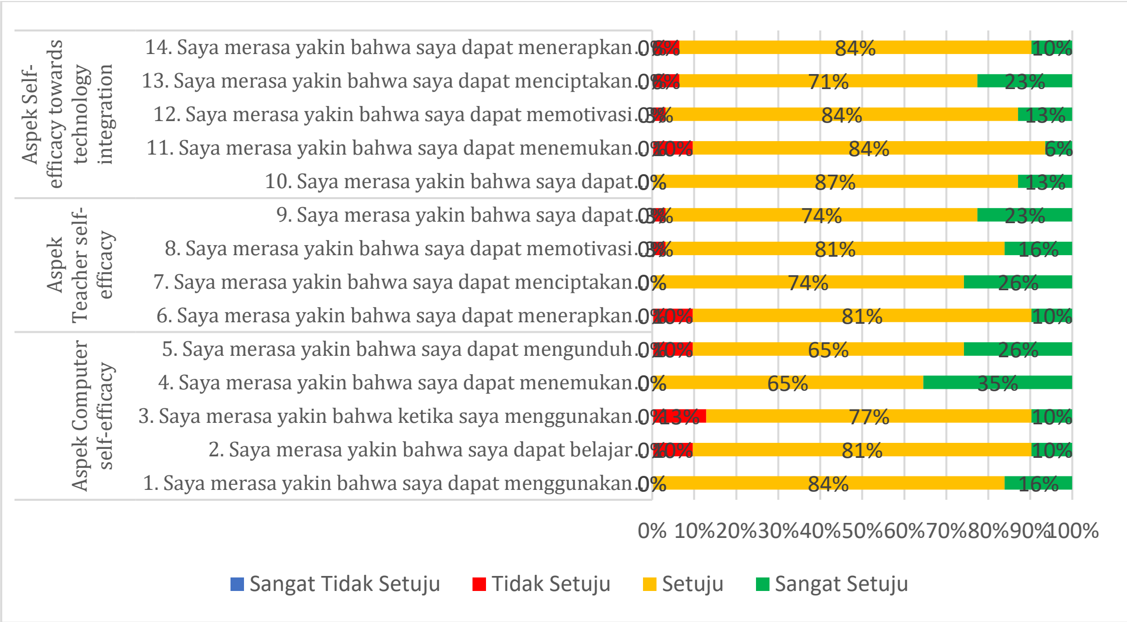

Figure 4. TISE Aspects

Discussion

The results of the study showed that in the realm of computer self-efficacy, there were students who felt unsure if they had to learn independently in using ICT independently. This indicates that not all students are enthusiastic about independent learning. Students who believe in their abilities will be more active in asking or answering questions, while students who feel incapable tend to be quiet and afraid (Kang et al., 2020; Makransky & Petersen, 2021; van Aalst et al., 2021). Self-Efficacy is an important factor underlying student motivation and plays an important role in their academic achievement (Haatainen et al., 2021; Makransky & Petersen, 2021). Self-Efficacy is a factor that can predict mathematics performance more strongly than other factors such as self-concept, anxiety, perception of the usefulness of mathematics, gender, or mathematics background (Martínez-Martí & Ruch, 2017; Rostika & Prihantini, 2019). There are about 13% of students who do not feel confident in solving technical problems that will arise. Technical problems such as applications that suddenly cannot be used. Almost all students feel confident that they can find useful ICT applications on the internet if they need them. This states that the level of student confidence is very high in finding new things. There are 10% of students who do not have confidence in being able to download programs on the internet, this is due to various factors such as network problems.

A teacher self-efficacy spec, in response to item 6, it is seen that 10% of students do not feel confident that they can apply various types of teaching methods to improve their students' learning later. This could be caused by factors of competence or student learning achievement. Students who have high self-efficacy also have high learning achievement. There is a positive relationship between self-efficacy belief and academic achievement and perseverance (Scherer et al., 2018) (McCoach & Siegle, 2007). Meanwhile, the response to item 7, it is known that almost 100% of students feel confident that they can create meaningful learning experiences for their students in the future. This is because students already have pedagogical competence on how to design meaningful learning for students. Students are also equipped with knowledge about learning theories, approaches, methods, strategies, techniques, and learning models that can be applied in mathematics learning. In item 8, it can be seen that students' responses generally feel confident that they can motivate students to be actively involved in their learning, although there are around 3% of students who feel unsure. Students are already equipped with pedagogical skills in the form of basic teaching skills. Students who have more teaching experience when implementing the Introduction to School Field (PLP) which is carried out in 3 stages of time, have higher confidence compared to students who have mediocre experience. The success of solving learning problems is an extraordinary experience. Frequent success will increase a person's self-efficacy while failure will decrease self-efficacy. If the success that someone gets is mostly due to factors outside themselves, it usually will not have an effect on increasing their self-efficacy. However, if the success is obtained through major obstacles and is the result of their own struggle, then it will have an effect on increasing self-efficacy. In item 9, it is known that 3% of students feel unsure about being able to develop teaching. This may be based on their experience during their teaching internship (PLP 1,2,3).

Self-efficacy aspect towards technology integration. In item 10, it is known that almost 13% feel unsure about being able to integrate ICT as a meaningful part of their teaching. This indicates that novice teachers do not feel fully prepared to integrate technology in the classroom (Admiraal et al., 2013; Makransky & Petersen, 2021; Tondeur et al., 2017). Students feel confident that they can integrate ICT as a meaningful part of teaching. Self-confidence in integrating technology is absolutely necessary for prospective teacher students. Technology Integration Self Efficacy (TISE) or self-efficacy in integrating technology in teaching is also a factor that can influence a teacher's decision to use technology in the classroom (Ariani, 2015). Increased teacher knowledge will lead to increased self-efficacy beliefs and potentially increased use of technology in the classroom and possibly increased use of technology based on content and pedagogical knowledge. In item 11, it is known that 10% of students feel unsure about finding new ways to apply ICT in teaching. In addition, in item 12, it is known that 3% of students feel unsure about being able to motivate students to use ICT in their learning. There are 6% of students who feel unsure about being able to create meaningful learning experiences for students, based on item 13.

Response to question item 14, it is known that there are 6% of students who feel unsure about implementing ICT to improve my students' learning. In the context of mathematics education, teachers who have a TPACK perspective are able to combine pedagogy, conceptual understanding, and the use of technology in teaching. By having the right TPACK, teachers can motivate students to be more explorative in understanding mathematics material. The TPACK model shows that content knowledge integrated with technology and pedagogical skills are important requirements in creating effective and innovative learning using technology (Heru et al., 2021; Lutfiana et al., 2023; Oktalia & Drajati, 2018). For prospective teacher students, the ability to use technology in teaching mathematics is important. Knowledge and skills, teachers must also have self-efficacy in integrating ICT with learning content that is appropriate to the background of students (Maira et al., 2022). The existence of TISE in teachers has an impact on the ability of teachers to adapt to existing technology in education (Kiray, 2016). Increasing teacher self-efficacy in integrating technology has a positive impact on the learning process (DLT et al., 2022; Ma et al., 2024).

Based on the results of the data description at the prospective analysis stage (HLT trial) and the metapedadidactic stage (pilot experiment and teaching experiment), the responses given by students were not all in accordance with predictions. Students' knowledge of ICT greatly supports students' TISE in mastering ICT. Students who have good ICT knowledge generally provide responses that are in accordance with predictions, and vice versa, weak ICT knowledge slows down the process of student assimilation and accommodation in integrating technology. Based on the results obtained at the prospective analysis stage and implementation at the metapedadidactic analysis stage, a picture is obtained of how the relationship between TPACK and TISE. TPACK in mathematics teachers depends on many factors, including experience in using the right technology when they learn mathematics at the college level (Ariani, 2015). Their content learning environment must exceed their expectations in emulating the learning models they have learned from their mathematics learning experiences. TPACK improvement in teachers' TPACK scores depends on the learning environment to improve competency in integrating technology. (Agyei & Voogt, 2012; Angeli & Valanides, 2009; Gao et al., 2011; Ottenbreit-Leftwich et al., 2010).

4. CONCLUSION

Based on the research results, the TISE level of prospective teacher students is in the moderate category, TPACK ability affects the TISE score. Prospective teacher students must have TISE so that they can present more meaningful learning. This research can be continued with research on other aspects related to TISE and TPACK.

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