**European Journal of Educational Research**
**Volume 13, Issue 1, 159 - 170.**
ISSN: 2165-8714
http://www.eu-jer.com/

# Technological Pedagogical Content Knowledge of Preservice Elementary Teachers: Relationship to Self-Regulation and Technology Integration Self-Efficacy

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*Received: March 9, 2023 ▪ Revised: May 3, 2023 ▪ Accepted: June 20, 2023*

**Abstract:** Technology integration into learning is essential to supporting educational reform. On the other hand, the relationship between self-regulation (SR), technology integration self-efficacy (TISE), and technological pedagogical content knowledge (TPACK) has yet to be thoroughly studied. This study investigated preservice elementary teachers and the connection between SR, TISE, and TPACK. A quantitative approach and a survey-based approach were both utilized in the research project. The research was carried out at one of Indonesia's universities, and the data collected were from 224 preservice elementary teachers in their fourth year through a questionnaire. According to the findings, preservice elementary teachers' SR, TISE, and TPACK levels were above average. Preservice elementary teachers scored the highest on planning capability (PC), monitoring and controlling skills (MC/CC), and making others use computer technologies self-efficacy (MUCTSE). In contrast, they scored the lowest on information and communication technology (ICT). Besides that, SR and TISE positively and significantly affected pre-service teacher TPACK. In light of the findings, it is of the utmost importance to enhance the competency of preservice elementary teachers in using technology to integrate learning.

**Keywords:** *Self-regulation, technology integration self-efficacy, TPACK.*

**To cite this article:** Sulistiani, I. R., Setyosari, P., Sa'dijah, C., & Praherdhiono, H. (2024). Technological pedagogical content knowledge of preservice elementary teachers: Relationship to self-regulation and technology integration self-efficacy. *European Journal of Educational Research*, *13*(1), 159-170. https://doi.org/10.12973/eu-jer.13.1.159

## Introduction

Information and communication technology (ICT) is an important and interesting topic in education. Integrating technology into learning is essential to support educational reforms in developing 21st-century skills. Educators need ICT skills to teach and improve technical skills in learning practice. Therefore, preparing prospective teachers to integrate technology in future classrooms is the main task of teacher education and training institutions (P. Liu, 2016; Ping et al., 2018; Sabzian et al., 2013).

Many countries have designed policies to prepare pre-service teachers to integrate technology in supporting 21st-century competencies (Robinson & Aronica, 2015). Researchers have discussed the development of knowledge for integrating pre-service teacher technology by connecting the three components of technological knowledge, pedagogy, and content, or what is known as technological pedagogical and content knowledge (TPACK) (Mouza et al., 2014; Sun et al., 2017). The TPACK framework emphasizes the importance of teacher choices in using technology to realize meaningful learning (Voogt & McKenney, 2017). When teachers intend to integrate technology, their beliefs in teachers influence their behavior and decision-making (Kramarski & Kohen, 2017).

Technology integration self-efficacy (TISE) refers to confidence in using technology in classroom learning (Birisci & Kul, 2019). When beliefs and attitudes about specific situations or opinions meet actual problems, concepts, or ideas, they can influence these relevant behavioral patterns (Rauf et al., 2017). Durak (2021) in his study notes that teachers can build self-confidence based on experiences with technology inside and outside the classroom. This study, involving 401 teachers, found that teachers who believe in the usefulness of technology can integrate technology into their classrooms to influence positive learning outcomes. Besides, TISE is the most powerful factor in influencing teacher behavior in using

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technology. Teachers with stronger TISE used more advanced instructional approaches connected to student learning (Joo et al., 2018).

Self-regulation is one of the factors in linking self-efficacy beliefs regarding technology integration and TPACK for preservice teachers (Chen & Jang, 2019). During the learning period, self-regulation provides supportive information about the internal and external environment (Pintrich, 2004; Wong et al., 2019). Studies show that SR plays a role in the success of preservice teachers in planning and implementing classroom learning (Chen & Jang, 2019; Tricarico & Yendol-Hoppey, 2012). Senkbeil and Ihme (2017) argue that understanding beliefs about using technology and supporting factors can help preservice teacher programs in successful technology integration. However, there has yet to be much empirical study of the connection between SR, TISE, and TPACK (Hsu, 2016; Kramarski & Michalsky, 2015). Hsu (2016) found that self-regulation directly affected TPACK but did not appear to affect teacher self-efficacy. In addition, Kramarski and Michalsky (2015) reported that self-regulation showed the strongest belief in influencing technology self-efficacy abilities, but not in the TPACK group. Focus and findings do not show the variables that affect self-efficacy towards TPACK. Therefore, further investigation is necessary. Additionally, few researchers have focused on the significant impact of SR on preservice teachers' self-efficacy in technology integration and their intention to use TPACK (Andyani et al., 2020; Cengiz, 2014; Chen & Jang, 2019). It is vital to conduct further research on comprehending preservice teachers and assisting them in implementing TPACK in their future classrooms.

This study aims to investigate important factors that contribute to increasing the integration of preservice teacher technology, including self-regulation and technology integration self-efficacy. In addition, this study also emphasizes that technology integration self-efficacy is a mediator linking self-regulation with preservice teacher TPACK competencies.

## Literature Review

### *Self – Regulation*

Self-regulation refers to regulating the development of a healthy life by adapting to various environmental conditions (Cleary et al., 2012). Several researchers, such as Zimmerman (2002), have developed the SR model, proposing another cyclical process in developing the SR phase: forethought, performance, and self-reflection. The forethought phase is related to task planning alongside learning objectives and strategies. At the same time, the performance process concerns adopting cognitive strategies and metacognitive knowledge and using information and communication technology (ICT) and motivational aspects to complete learning tasks. Conversely, the self-reflection phase refers to evaluating various learning tasks. Pintrich (2004) also developed the concept of four SR phases: planning, monitoring, control, and reflection. Phase 1, the planning stage, involves setting goals, designing teaching materials and procedures for tasks, and determining the appropriate learning locations and evaluation methods. Phase 2, the monitoring stage, entails evaluating assignments during teaching and learning and assessing student responses. Phase 3 is controlled and refers to selecting cognitive strategies for learning activities, alongside properly adjusting the materials, methods, and technologies used. Finally, phase 4 is the reflection stage, which involves evaluating actions and observing students' responses during the learning process. SR is considered one of the critical factors influencing learning success and academic performance (DiFrancesca et al., 2016; Virtanen et al., 2017). This attracts many researchers to study and explore SR in the teaching and learning process (Matric, 2018).

In recent years, SR has proven to be an important indicator in evaluating and predicting the professional preparation program for pre-service teachers. Kramarski and Michalsky (2010) measured SR and its relationship with TPACK for 95 pre-service teachers, consisting of 57 females and 38 males divided into two groups of professional development programs. Then, Kramarski and Kohen (2017), using 90 participants, performed follow-up research to explore the role of SR in the dual function of pre-service teachers as proficient learners and productive teachers. Similarly, J. Liu et al. (2020) measured the SR component and academic achievement of preserving physics teachers and found moderate cognitive and metacognitive strategies. Cognitive and metacognitive strategies were moderate. Other studies have also found that SR is widely associated with pre-service teachers learning mathematics, self-efficacy, motivation, and achievement (Broadbent & Poon, 2015; Sukowati et al., 2020). Based on these findings, SR was hypothesized to influence pre-service elementary teachers' learning during professional development preparation programs.

The measurement of SR has been thoroughly explored via several valid instruments, such as the SR motivation questionnaire, the self-learning readiness survey, and the SR survey (Pintrich, 2004). Generally, the measurement should be contextualized according to the research criteria, particularly the population group and context. Chen and Jang (2019) adapted the Pintrich model to develop a secondary school teacher SR questionnaire. Narrative items are created to align with the learning components, including objectives, materials, strategies, and evaluations. This SR model has four components, namely planning capability (PC), Monitoring and control capability (MC/CC), Information and communication technology-connecting capability (ICT-C), and reflection capability (RC). Due to its extensive use in exploring SR at the school and college education levels, the SR questionnaire developed by Chen and Jang was adapted and applied in this research.

*Self-Efficacy for Technology Integration*

Technology integration self-efficacy (TISE) reflects confidence in seeing, acting, and assessing the success of technology integration in classroom learning. This belief can determine the comfort of using technology during teaching by individuals who engage in certain activities and express positive attitudes (Govender & Govender, 2009). TISE is one of the important factors influencing technology integration in the classroom. In primary education, Wang et al. (2004) developed the TISE instrument to study the effect of experiential learning on self-efficacy in integrating technology in the classroom. This instrument by Wang has been adopted in several studies and developed into different validation versions. Therefore, preservice teachers must develop these attributes during the professional preparation program.

The study by Keser et al. (2015) examined the technology integration self-efficacy perceptions and technopedagogical competency level of 713 preservice teachers who were freshmen and seniors according to gender, class level, and program. According to the findings of this study, preservice teachers demonstrate a high level of TPCK competency and self-efficacy perception regarding technology integration. Furthermore, there was a statistically significant difference in technology integration self-efficacy beliefs based on the class level of preservice teachers; however, there was no statistically significant difference based on gender. Similarly, the study by Abbitt (2011) provided 45 preservice teachers with 16 hours of training on the use of technology in education over a semester. According to the study's post-test results, a significant correlation existed between preservice teachers' perceptions of their technology integration self-efficacy and their TPCK knowledge. This study also found that efforts to cultivate TPCK knowledge among preservice teachers increased their perceptions of self-efficacy. Birisci and Kul (2019) found a significant, positive, and high-level correlation between perceptions of technology integration self-efficacy and technopedagogical competence among 174 preservice teachers participating in various programs. Moreover, they discovered that sub-dimensions of technopedagogical education competency, such as ethics, design, labor, and proficiency, substantially predict perceived self-efficacy regarding technology integration. Also, Unal (2013) discovered a moderately positive correlation between prospective teachers' perceived technology integration self-efficacy and TPCK.

*Technological Pedagogical Content and Knowledge (TPACK)*

The TPACK is a framework for integrating technology into teacher learning in the classroom. This framework draws on the approach used by Shulman to incorporate technology into teacher pedagogy and content knowledge to create effective learning processes with different groups of students. This framework relies on the basic knowledge areas of technology (TK), pedagogy (PK), and content (CK), which are integrated to produce TPACK (Harris et al., 2009). Chai et al. (2011) further developed and applied this concept to 834 pre-service primary school teachers in Singapore to reveal the seven factors underlying valid and reliable TPACK framework instruments. The research results by Chai (2010) note that teacher TPACK influences learning through the quantity and quality of learning technology in the classroom. This suggests that improving pre-service teachers' ability will likely improve learning and teaching and even advance student literacy.

The ability to use technology is an important characteristic that all teachers must have (Keser et al., 2015). However, technology-related courses given with the aim of successful technology integration may be insufficient to prepare pre-service teachers (Birisci & Kul, 2019). In addition, newly-graduated teacher candidates require higher levels of computer technology proficiency to be effective in the classroom (Andyani et al., 2020). According to findings from a study by Birisci and Kul (2019), most prospective teachers state that technology has an important role in education; however, they identified that some teacher candidates needed to be more comfortable discussing specific uses of technology due to a lack of knowledge. Consequently, teacher education programs should focus on how teachers' affective attitudes affect integrating technology with pedagogical knowledge and content (Hew & Brush, 2007).

In recent years, researchers have begun to address the role of effective factors in teachers' TPACK development. For instance, Kramarski and Michalsky (2015) proposed the TPACK-SRL approach, in which SRL was used as a springboard to assist instructors in integrating technology, pedagogy, and content. They argued that SR enables teachers to consider specific techniques or personal experiences within each TPACK component and relate them to the others. SR also guides teachers in planning and taking action to accomplish the goals of each component. Together, SR helps teachers ruminate on their technology integration decision-making and enables them to internalize and connect the three pillars of TPACK. Notably, Kramarski and colleagues emphasize the significance of self-questioning in terms of what, when, how, and why so that instructors can continue to refine their beliefs, decisions, and actions regarding technology-based teaching.

Keser et al. (2015) examined the technology integration self-efficacy and technopedagogical education ability of 713 first- and fourth-year student pre-service teachers by gender, class level, and program. This study found that pre-service teachers had excellent TPCK competency and technology integration self-efficacy. Technology integration self-efficacy beliefs differed by pre-service teacher class level but not by gender. Another study by Unal (2013) found a significant, positive, and high-level correlation between the perceptions of technology integration, self-efficacy, and TPACK competency among 748 pre-service teachers enrolled in various programs. In addition, they discovered that the subdimensions of TPACK competency substantially predicted perceptions of self-efficacy regarding technology integration. Also, Cengiz (2014) discovered a moderate positive correlation between pre-service teachers' technology integration self-efficacy perception and TPACK.

## Methodology

*Research Design*

This quantitative research examined the relationship between pre-service elementary teachers' perceptions of TPACK competencies, SR, and TISE. Figure 1 represents the assumption of this research based on previous research on SR, TISE, and TPACK. The structural model formed was tested using structural equation modeling (SEM) with the statistical package for social sciences (SPSS) 24.0 and AMOS 24.0. Meanwhile, the analytical strategies used include constructing the SR, TISE, and TPACK of pre-service elementary teachers by measuring the confirmatory factor analysis (CFA) to ensure the validity and structure of the construction. Model fit was evaluated by the comparative fit index (CFI), Tracker-Lewis index (TLI), the normed fit index (NFI), root-mean-square error of approximation (RMSEA), etc. The structural model was tested by examining the relationships among the latent variables and detecting the fitness of the proposed models. Also, the criterion limit for the recommended fit index by (Meyers et al., 2016) was employed, and the model fit cutoff values were 0.90 for CFI and NFI alongside a score of 1 for RMSEA.

*Participants*

This study explores experiences and perceptions of self-regulation, technology integration self-efficacy, and pedagogical content knowledge among pre-service elementary teachers. The sample consisted of pre-service elementary teachers who had followed the introductory program for educational institutions and had two-semester experience in the field. The random sampling method was then used to ensure equal selection opportunities and recruited 224 students out of a total population of 276.

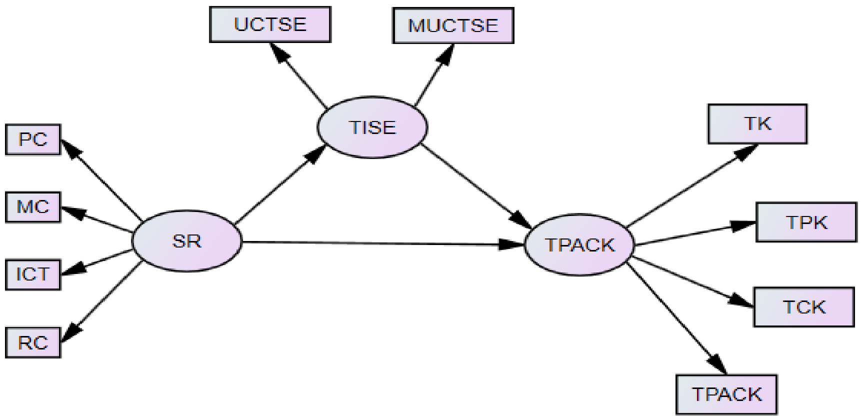


*Figure 1. The Hypothetical Model of Structural Relations among SR, TISE, and Preservice Elementary Teachers' TPACK*

As shown in Table 1, the majority of respondents were female, amounting to 156 (69.64%), and aged between 19–21 years (35.71%) and 22–24 years (59.82%). Then, 51 (22.77%) chose social sciences as their field of specialization in teaching, 39 (17.41%) picked mathematics, 38 (16.96%) persons each selected Indonesian language and Arts, while 29 (12.95%) each chose sciences and religious education.

*Instrument*

This research instrument consisted of two stages. In the first stage, the research instrument contains demographic factors that explain the respondents' background, including gender, age, and teaching materials. In the second stage, the research instrument includes three components of the research variables: the TPACK instrument consisting of TK, TCK, TPK, and TPACK consisting of 17 statement items.

Wang et al. (2004) created the technology integration self-efficacy scale. The Turkish version of the technology integrated sense of efficacy scale (TISES) was adopted by Unal (2013). It consists of 11 items divided into two dimensions: self-efficacy in using technology for one's purposes (such as "I believe that I have the skills to use computers for testing purposes") and encouraging others to do the same (e.g., I believe that I can give individual feedback to my students when they use technology").

Because no other SR instruments target secondary science instructors in Taiwan, we used Chen and Jang (2019) SR scale. Planning capability (e.g., "before teaching, I carefully choose the content according to my knowledge level and technology skills."), Monitoring and controlling capability (e.g., "During my teaching, I always keep track of the effectiveness of my methods and strategies. "), reflective capability (e.g., "I reflect on the effectiveness of the methods and strategies that I used for teaching."), moreover, information and communication technology (e.g., "During teaching, I use...") are the four dimensions.

*Table 1. Respondents' Demographic Background*

| Variable | Category | Total | Percentage |
|---|---|---|---|
| Gender | Male | 68 | 30.3 |
| | Female | 156 | 69.6 |
| Age | 19 - 20 years | 80 | 35.7 |
| | 21 - 22 years | 134 | 59.8 |
| | 23 - 25 years | 10 | 4.4 |
| Specialize in teaching | Indonesian language | 38 | 16.9 |
| | Sciences | 29 | 12.9 |
| | Social Sciences | 51 | 22.8 |
| | Mathematics | 39 | 17.4 |
| | Arts | 38 | 16.9 |
| | Religious Education | 29 | 12.9 |

Cronbach's alpha values for the overall scale were.868, and the subscales' PC, MC/CC, RC, and ICT scores were .788, .843, .860, and .833, respectively, indicating high reliability. Internal consistency for the total scale was .859, with Cronbach's alpha values of .803, .803, .874, and .874 for the TK, TPK, TCK, and TPACK subscales, respectively. The internal consistency of the whole scale was .892, whereas the UT and MT subscales' Cronbach's alphas were .866 and .872, respectively. The survey was read over by four educators who suggested improving the text and clarifying any problematic terminology during its creation. Elementary education and psychology experts then checked the material for accuracy and validity.

## Findings/Results

*Pre-Service Elementary Teacher's Self-Regulation*

Table 2 shows the pre-service teachers' self-regulation outcomes, including planning capability, monitoring and controlling capability, information and communication technology capability, and reflecting capability. Their capacity to choose instructional content and login to websites or platforms was higher than their ability to define goals, locate the materials of a lesson, and choose the content, for a total mean score of 3.52, indicating a relatively high average. In addition, the participants' average score on a test measuring their ability to monitor and manipulate the learning environment was 3.42, suggesting that their understanding was slightly above average. The participant's ability to evaluate the content and track the efficacy of approaches and tactics was also highlighted. Results showed that future educators have above-average ICT skills (Mean = 3.06). The results showed that, for this ICT competence, participants were more able to make effective use of technology and apply technology in real-world conditions than to reflect on the usefulness of the technology. Moreover, the results showed that participants had somewhat above average reflecting competence (Mean = 3.31), with a greater capacity to reflect on their teaching plans and the efficacy of their methods and tactics than on the plans and strategies of others. Most mean scores are somewhat above average, suggesting that pre-service teachers demonstrated above-average levels of self-regulation.

*Table 2. Mean Scores Participants to Items of Self-Regulation.*

| Self Regulation | Mean | Standard Deviation |
|---|---|---|
| **Planning Capability (PC)** | | |
| 1. Set goals | 3.53 | 0.71 |
| 2. Choose the content | 3.34 | 0.69 |
| 3. Login to websites or platforms | 3.60 | 0.71 |
| 4. Locate the materials of a lesson | 3.51 | 0.72 |
| 5. Choose teaching content | 3.62 | 0.68 |
| **Mean** | **3.52** | |
| **Monitoring and Controlling Capability (MC/CC)** | | |
| 1. Accomplish tasks on time | 3.29 | 0.68 |
| 2. Use teaching materials | 3.33 | 0.67 |
| 3. Understand the content teaching | 3.73 | 0.61 |
| 4. Review the material | 3.82 | 0.76 |
| 5. Monitor the effectiveness of methods and strategies | 2.98 | 0.63 |
| 6. Evaluate the effectiveness of materials | 3.35 | 0.64 |
| **Mean** | **3.42** | |

*Table 2. Continued*

| Self Regulation | Mean | Standard Deviation |
|---|---|---|
| **ICT Capability** | | |
| 1. Effectiveness use of technology | 3.12 | 0.70 |
| 2. Use of technology according to actual situations | 3.18 | 0.59 |
| 3. Reflect on the effectiveness of technology | 2.88 | 0.72 |
| Mean | **3.06** | |
| **Reflecting Capability** | | |
| 1. Reflect on the teaching goals | 3.34 | 0.67 |
| 2. Reflect on teaching plans | 3.41 | 0.58 |
| 3. Reflect on the teaching task | 3.22 | 0.54 |
| 4. Reflect on strategies to make improvement | 3.32 | 0.61 |
| 5. Reflect on practical methods and strategies | 3.43 | 0.63 |
| 6. Reflect on the effectiveness of evaluation methods | 3.19 | 0.69 |
| **Mean** | **3.31** | |

*Table 3. Mean Scores Participants to Items of TISE*

| Technology Integration Self Efficacy | Mean | Standard Deviation |
|---|---|---|
| **Use of Computer Technologies Self-Efficacy** | | |
| 1. Skills using technology | 3.64 | 0.68 |
| 2. Teach the material using the right technology | 3.29 | 0.70 |
| 3. Complete technology-based work | 3.44 | 0.66 |
| 4. Using effective technology | 3.17 | 0.65 |
| 5. Incorporating technology into teaching | 3.05 | 0.65 |
| **Mean** | **3.32** | |
| **Making others use computer technologies self-efficacy** | | |
| 1. Monitor students in the use of technology | 3.27 | 0.66 |
| 2. Provide feedback during technology use | 3.43 | 0.63 |
| 3. Be responsive during the use of technology. | 3.09 | 0.63 |
| 4. Motivating in technology-based projects | 3.29 | 0.70 |
| 5. Help students when they have difficulty with technology | 3.54 | 0.64 |
| 6. Use of technology resources | 3.67 | 0.66 |
| **Mean** | **3.38** | |

*Pre-Service Elementary Teacher's Technology Integration Self Efficacy*

Technology integration self-efficacy data, including utilize of computer technology self-efficacy and making others use computer technologies, are presented in Table 3. The average score on the competence self-assessment in using IT was 3.32, somewhat above average. Self-Confidence in utilizing technology is stronger than in completing technology-based work, teaching content with the appropriate technology, employing effective technology, or incorporating technology into teaching. Teachers-to-be had a somewhat above-average sense of confidence in their ability to convince people to use technology, with a mean score of 3.38 on a 5-point scale. Participants' self-efficacy in accessing technological resources (Mean = 3.67) and assisting students who are having trouble with technology (Mean = 3.54) was revealed to be above average. While the other indicator shows slightly above-average performance, it is important to note that participants' self-efficacy in monitoring students' use of technology, providing feedback during technology use, being responsive during technology use, and motivating in technology-based projects is above average.

*Pre-Service Elementary Teacher's TPACK*

Technology knowledge, pedagogical technology knowledge, content technology knowledge, and ICT – TPACK is the four subcomponents that makeup TPACK competency in this analysis. Table 5 displays the mean scores given by the pre-service teachers who took the survey on each of the survey's relevant questionnaire items. The results demonstrate that pre-service teachers had slightly above-average levels of knowledge across the board in terms of technology (Mean = 3.25), technology pedagogy (3.35), technology content (3.26), and technological pedagogical content (3.17). The findings indicate that future educators have a solid grasp of effectively implementing ICT in their classrooms.

*Table 4. Mean Scores Participants to Items of TPACK*

| TPACK | Mean | Standard Deviation |
|---|---|---|
| **Technology Knowledge** | | |
| 1. Skills to use technology effectively | 3.01 | 0.68 |
| 2. Learn technology easily | 3.51 | 0.69 |
| 3. Know how to solve problems when using technology | 2.87 | 0.76 |
| 4. Keep up with new technology | 3.62 | 0.67 |
| **Mean** | **3.25** | |
| **Technological Pedagogical Knowledge** | | |
| 1. Use technology for learning | 3.62 | 0.65 |
| 2. Facilitating students' use of technology to plan and monitor learning | 3.53 | 0.65 |
| 3. Facilitating students to use technology to build knowledge representations | 2.98 | 0.64 |
| 4. Facilitate students to collaborate using technology | 3.27 | 0.71 |
| **Mean** | **3.35** | |
| **Technology Content Knowledge** | | |
| 1. Using software | 3.24 | 0.57 |
| 2. Know technology to teach material | 3.05 | 0.63 |
| 3. Using media (computers, Microsoft, projectors, multimedia in the learning process) | 3.65 | 0.6 |
| 4. Understand the material that requires technological facilities | 3.11 | 0.65 |
| **Mean** | **3.26** | |
| **ICT - TPACK** | | |
| 1. Designing lessons that integrate content, technology, and pedagogy | 3.42 | 0.65 |
| 2. Formulate knowledge content and facilitate with appropriate tools (e.g., Edmodo, Google Classroom, Blog, Webquests, etc.). | 3.22 | 0.68 |
| 3. Help students build content knowledge representations using appropriate icts | 3.13 | 0.6 |
| 4. Create independent learning activities from knowledge content with appropriate ICT tools | 3.08 | 0.65 |
| 5. Designing inquiry activities to guide students to understand content knowledge with appropriate ICT tools | 2.98 | 0.62 |
| **Mean** | **3.17** | |

The average score for technology knowledge was 3.25, which is just over average. The indicator shows that people are slightly above average in their ability to learn new technologies quickly (3.51), adapt to changing technologies (3.62), and make productive use of technology (3.01). The mean participant score for TPK was 3.35, suggesting a slightly above-average level of TPK across the participants. Participants' awareness of utilizing technological resources for instruction and students' ability to use such tools for instructional planning and monitoring learning were moderately high (Mean = 3.62 and 3.53). Meanwhile, the other metric shows both above- and below-average performance. With an average of 3.26 on technological content knowledge, the participants' TCK was slightly higher than typical. All indicators point to a somewhat above-average performance in this area. The indicator was proficiency in using media (Mean = 3.65) and software (Mean = 3.24), as well as knowledge of teaching content in a technological environment (Mean = 3.11 and 3.05, respectively).

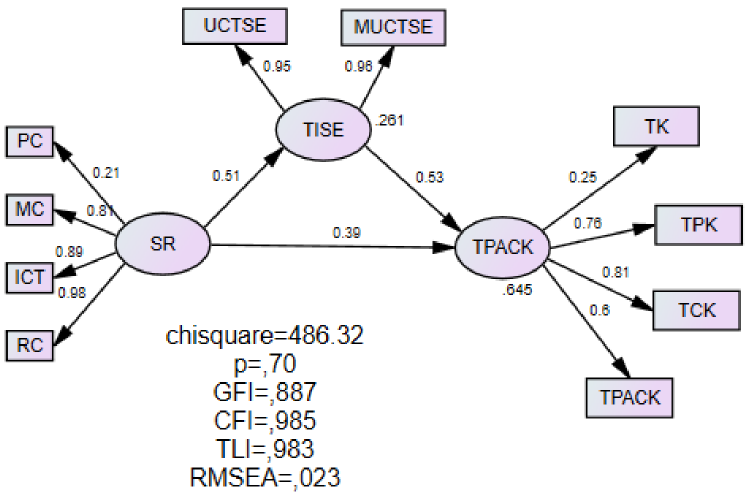


*Figure 2. Structural Equation Model Test Results*

The participants' technological pedagogical content knowledge (TPACK) was slightly above average, with a mean score of 3.17. Participants' competence in creating inquiry activities to enable students to understand content knowledge with appropriate ICT tools was somewhat below average (Mean = 2.98) and slightly above average (Mean = 2.98), respectively.

*Structural Equation Model (SEM) Analysis*

The first analysis presents respondents' responses to statements about self-regulation, technology integration self-efficacy, and technological pedagogical content knowledge in implementing their learning. The second analysis tested the complete structural equation modeling (SEM) analysis. Full SEM model testing refers to the model fit criteria in the goodness of fit index table.

The SR, TISE, and TPACK values were analyzed using AMOS 24. Figure 2 summarizes the final processing results of the complete model after removing the insignificant path coefficients and adding the relevant ones based on the modified index. The final SEM results showed a model with a perfect fit, with X2 value = 486.32, Cmin/def value = 1.079, and GFI, CFI, TLI, and RMSEA values. 887. 985. 983 and 0.023, respectively. Overall, the final model was acceptable. The model analysis in Figure 2 shows that Self-Regulation (b = 0.51) is statistically significant in predicting technology integration self-efficacy. Self-regulation (b = 0.39) and technology integration self-efficacy (b = 0.53) were statistically significant in predicting pedagogical technology and knowledge content. In addition, this self-regulation variable predicts and accounts for 26.1% of technology integration self-efficacy. Meanwhile, the variable self-regulation and technology integration self-efficacy predicts and contributes 64.5% to the TPACK competence of pre-service elementary school teachers.

## Discussion

This study focused on preservice teachers' TPACK, self-regulation, and technology integration self-efficacy. We discuss the findings and compare them to previous research on the three types of knowledge.

The SR of preservice elementary teachers in this study was sufficiently above average (with all dimension mean scores over 3.00 on a 5-point scale), with the PC dimension being the highest and the ICT the lowest, which is consistent with previous research on apprentice teachers' Taiwanese high school (Chen & Jang, 2019). Again, this study supports previous research by Kramarski and Kohen (2017), showing that relatively high CK and PCK scores can be associated with years of cumulative teaching experience that build teacher content knowledge in in-service and instructional representations and strategies. Self-regulation is one factor that influences preservice elementary teachers' achievement in teaching practice (Sukowati et al., 2020), and high self-regulation influences achievement (Chen & Jang, 2019). Unlike the PC, participants' ICT capability is the lowest of the four dimensions. We assume that because of the uneven deployment of technology across the country, preservice elementary teachers may not be able to develop their technology-related SR fully. Given the findings discussed here, it is recommended that teacher education programs give good advice and support for professional development (Chen & Jang, 2019; Lin et al., 2017) so that preservice teachers can expedite the development of SR linked with teaching practice.

The indicator with the most significant influence of .96 on the Technology Integration Self-Efficacy variable measures teacher confidence in using technology. The findings of this study are consistent with those of Durak (2021), who discovered that instructors' confidence in their ability to integrate technology into the classroom would favor learning objectives. This study also supports the findings of Keser et al. (2015), which involved 713 pre-service teachers and found that their confidence in using technology affected their perspectives on technology integration in the classroom. Similarly, Abbitt (2011) conducted a study in which 45 teacher candidates received 16 hours of training on the use of technology in education over one semester. According to post-test research findings, a significant correlation exists between pre-service teachers' perceptions of their technology integration self-efficacy and their TPCK knowledge. The teacher professional development program also boosts preservice students' confidence to integrate technology and demographic characteristics, such as gender and prior technological expertise (Cengiz, 2014; Xie et al., 2017).

This study examines the TPACK of pre-service primary school teachers as the third part of their competency. The results of the analysis show that the average pre-service teacher has TPACK competence in the high category, with the largest TCK dimension of .86. Pre-service teachers use a lot of technical instruments, such as technology (computers, multimedia learning), new technology, and the new technology itself. These results are consistent with the findings of Chai (2010), noting that increasing the ability of pre-service teachers to use technology (computers, internet, and new technologies) affects TPACK competence and the quality of learning in the classroom. This data supports the conclusion of Agyei and Voogt (2015) that teacher-candidate pedagogy has improved due to TPACK-based learning. This is also consistent with the findings of Fan and Mailizar (2020) study, which concluded that student performance improved while acquiring designing activities and ICT TPCK abilities.

According to the findings on technological pedagogical content knowledge, technology integration self-efficacy, and self-regulation, the technology-related views of preservice elementary teachers are not lower than those of other subject matter preservice teachers in other countries (Niederhauser & Perkmen, 2010). Even so, the participants in the current study had a view of technology pedagogical subject knowledge that was slightly higher than the findings that Chai et al. (2010) found for Singaporean preservice teachers.

According to the findings of this study, there are significant and positive connections between the variables that measure technological pedagogical subject knowledge and those that measure self-efficacy and self-regulation in technology integration. It was revealed that the correlations between technology integration self-efficacy and TPACK were significantly stronger than those between self-regulation and TPACK. Similarly, (Cengiz, 2014) discovered moderate associations between pre-service teachers' technological pedagogical topic knowledge and their self-efficacy in technology integration across four distinct subject areas (math, science, literacy, and social studies). Doo and Bonk (2020) showed a significant association between integrating technology and self-regulation in another study conducted with pre-service teachers. This study included primary and early childhood instructors.

In conclusion, this research reveals that training educators in the maintenance of ICT knowledge and the application of ICT in educational settings is essential. Rather than simply providing training on the technical knowledge required to use ICT resources, offering training courses emphasizing the link between pedagogy and the content of integrating ICT would be preferable. This has received substantial backing from the research evidence presented in the published works (Agyei & Keengwe, 2014; Hew & Brush, 2007; Koehler & Mishra, 2005; Qu et al., 2019). For instance, Koehler and Mishra (2005) propose the argument that when educating instructors to integrate ICT into teaching, it is necessary to educate information and communications technology (ICT) in situations that demonstrate the link between technology, content, and pedagogy.

## Conclusion

This past decade, the investigation of future teachers' TPACK has become increasingly valuable. This research is still important for comprehending and enhancing how technology is incorporated into the classroom. The TPACK, self-regulation, and technology integration self-efficacy of preservice teachers were the primary foci of this study. We discuss the findings and their relationship to the research on the three knowledge types.

This study investigates the relationship between SR, TISE, and TPACK and provides supporting evidence. SR and its indicators have a positive and significant correlation with technology integration self-efficacy and pre-service teacher TPACK competence, according to the findings of this study. In addition, the self-efficacy attitude toward technology integration also correlated positively and significantly with the TPACK of elementary school teachers. These results will serve as guidelines for institutions responsible for the professional development of teachers, especially those teaching in technology-enabled classrooms. This research also contributes to a greater understanding of the influence of teacher preparedness on issues, such as attitudes toward technology integration. This study's findings also promise to overcome challenges in technology integration and enhance future teachers' knowledge, skills, and dispositions regarding technology integration. A second finding was that SR was an effective method for contributing positive attitudes towards self-efficacy and technology integration to a successful technology integration process.

## Recommendations

In future research, elementary teachers could be recruited for comparison with our current findings regarding pre-service elementary teachers. Future research could also investigate how instructors employ technology. Future research should incorporate multiple data sources to capture a broader spectrum of phenomena about the same topic. Future research can examine how cultural differences affect teachers' perceptions of technology usage by comparing other groups of teachers from diverse cultural contexts. Several factors influencing teachers' intentions to use technology can also be investigated. One must consider technology-related experiences, school support for technology use in the classroom, and teacher concerns to observe the various dynamics in technology-oriented learning environments.

## Limitations

This research contains some flaws. The first issue is that elementary conservation teachers' SR, TISE, and TPACK are only evaluated through self-assessment measures and are subject to bias in improving results. Second, the study assessed teachers' cognitive and metacognitive abilities to determine their SR. However, SR also includes behavioral, affective/motivational, and environmental rules.

### Conflict of interest

The authors declare no conflict of interest

### Funding

No funding source is reported for this study.

### Authorship Contribution Statement

Sulistiani: Contributed to conceptualization, design, data acquisition, data analysis, Interpretation, and writing of the research. Setyosari: Contributed to editing, critical analysis, and final approval. Sa'dijah: Contributed to editing, statistical analysis, and final approval. Praherdhiono: Contributed to reviewing and material support.

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