The effectiveness of the TPASK-C approach practicum model in improving self-efficacy and research skills of prospective biology teachers

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Abstract
This study aims to investigate the effectiveness of implementing the Technological Pedagogical and Science Knowledge-Contextual (TPASK-C) practicum model in improving the self-efficacy and research skills of prospective biology teachers. This study employs a quasi-experimental design with a pretest-posttest control group. Research data were collected using tests and non-tests. Test data were used to collect research skills data. Self-efficacy data were collected using questionnaires. Research data were analyzed using qualitative and quantitative techniques, as well as effect-size analysis, to analyze the effectiveness of the treatment given to the tested variables. The results of the study found that the TPASK-C practicum model made a significant contribution to the formation of self-efficacy and research skills in prospective biology teacher students. The results of the t-test on the achievement of self-efficacy and research skills showed a sig. α <0.005, which indicated a significant difference between the two classes tested. Effect size testing showed Cohen's d values (1.338 and 1.469), indicating that TPASK-C is effective in equipping students with self-efficacy and research skills. The results of this study are expected to be an alternative practicum model that can be widely applied in teacher training institutions (LPTK) to facilitate efforts to improve self-efficacy and research skills in prospective biology teacher students in Indonesia.

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1. Introduction

The education of prospective 21st-century teachers is expected to develop teacher competencies that enable them to respond to the challenges of the times. Twenty-first-century biology teachers are required to possess holistic competencies, not only mastering biology content but also being skilled in integrating technology, pedagogy, and teaching materials in context (Koehler et al., 2009; Mishra & Koehler, 2006). Prospective biology teachers must possess strong self-efficacy and research skills as essential foundations for building the holistic competencies required in the 21st century. In this regard, practicums, as the heart of science learning, play a crucial role in developing research skills and building the self-efficacy of prospective science teachers (Wibowo et al., 2019; Iaochite & Da Costa Filho, 2016).

Practicum activities should facilitate the development of self-efficacy and research skills in prospective science teachers, but in reality, these activities do not fully equip these two skills. This occurs because conventional practicums often focus on concept verification, leaving little room for exploration, discovery, and application of technology. As a result, prospective teachers are poorly trained in designing research, collecting and analyzing data, and integrating technology into learning. Practicums should enhance research experiences and integrate technology into learning teachers (Jenssen & Haara, 2024; Troesch et al., 2023). Teachers who can integrate technology and science into real-life contexts can guide students to understand and find solutions to complex environmental problems, which is the essence of holistic 21st-century competencies.

Technology integration in modern education is often guided by the TPACK framework (Koehler et al., 2009). While fundamental, TPACK has limitations due to its generic nature, which makes it unable to fully

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address the unique needs of biology education, as it demands contextual learning and the development of relevant research skills. This gap is even more significant in the Indonesian context. First, teachers' mastery of TPACK in Indonesia has been shown to require further development (Rochintaniawati et al., 2019). Second, research consistently shows that psychological factors such as self-efficacy are key predictors of teacher success in adopting technology; pre-service teachers with high self-efficacy are more likely to integrate technology effectively (Al-Awidi & Alghazo, 2012). While the importance of each component (TPACK, context, self-efficacy, and research skills) has been widely discussed separately, there is a research gap regarding learning models that integrate all these elements holistically. In particular, there has been limited research on the development and testing of practicum models that can simultaneously improve mastery of contextual science content, self-efficacy, and research skills for prospective biology teachers.

Research by Caprara et al., (2006) shows that teacher self-efficacy influences student job satisfaction and academic achievement. Self-efficacy is believed to influence behavior and choices, thereby affecting the actions taken (Bandura, 1997). Self-efficacy and emotional control play an important role in science learning. Self-efficacy is related to emotional control in teachers. Teachers with high self-efficacy feel more comfortable and competent in teaching science (Brígido et al., 2013). Training self-efficacy in prospective teacher students can be done through appropriate methods/approaches.

One approach that can facilitate the development of self-efficacy in prospective teachers is the Technological Pedagogical and Content Knowledge-Contextual (TPACK-C) Approach. This approach integrates TPACK, NoS (Nature of Science), and contextual approaches into one package known as TPASK-C. This approach is unique because it has a specific subject matter, namely science (biology), and is oriented towards learning that addresses issues and phenomena in the surrounding environment through practical activities. TPASK-C integrates science, teaching, and learning with technology and NoS subject matter (Widowati et al., 2020). In addition, it adds context linked to content (contextual learning). This model integrates TPACK with an applied context, emphasizes the development of research skills through problem-based practicals, and encourages the use of technology as a tool for scientific exploration and communication.

Several studies have demonstrated the potential of the TPASK-C Approach in improving student learning outcomes and teacher competency (Archambault & Barnett, 2010; Wang et al., 2018; Chai et al., 2013). However, research specifically examining the effectiveness of the TPASK-C Approach in enhancing the self-efficacy and research skills of prospective biology teachers remains limited. Therefore, this study aims to complement the TPACK framework, which is explicitly used in science education contexts, by developing a contextualized version called TPASK-C, to facilitate prospective biology teachers in developing self-efficacy and research skills. The results of this study are expected to make a significant contribution to efforts to improve the quality of education for prospective biology teachers in Indonesia.

2. Method

This study used a quasi-experimental method with a pretest-posttest control group design (Fraenkel & Wallen, 2006) . The subjects were fifth-semester students in the Biology Education Study Program at UIN Syekh Nurjati Cirebon in the 2024/2025 academic year, divided into two groups: the experimental class (n = 31) and the control class (n = 31). The experimental class received treatment in the form of a practical model with the Technological Pedagogical and Science Knowledge-Contextual (TPASK-C) Approach. In contrast, the control class used regular learning with an inquiry approach. The research procedure is presented in Figure 1.

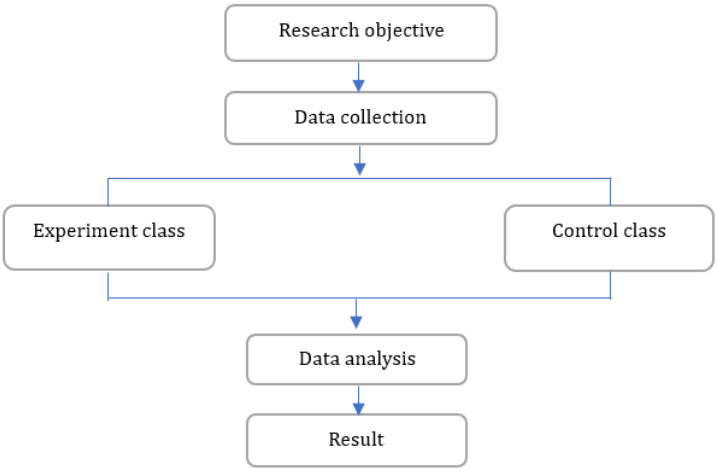

Figure 1. Research Procedure

Data collection was conducted using two types of instruments: tests and non-tests. A multiple-choice test was used to measure students' research skills, developed from the Research Skills Development (RSD) indicators by Willison (2018) and encompassing three research stages: planning, implementation, and reporting. The test consisted of 20 multiple-choice items. Meanwhile, self-efficacy data were collected through a non-test instrument in the form of a closed-ended questionnaire whose indicators were developed from theory (Bandura, 1997), covering personal efficacy in teaching science and the outcomes of science teaching. The questionnaire instrument used to measure self-efficacy consisted of 20 items. The results of the self-efficacy instrument test showed a Cronbach's alpha of 0.876 and the research skills instrument a Cronbach's alpha of 0.784, indicating that the instrument used had reliability.

The data analysis techniques used were quantitative and qualitative. Prior to hypothesis testing, prerequisite tests were conducted, including normality and homogeneity tests. The data were analyzed using descriptive and inferential statistics using t-tests to identify significant differences between the experimental and control groups. Furthermore, to measure the effectiveness of the treatment, an effect size analysis was performed using Cohen's d (Cohen, 1992).

3. Results and Discussion

3.1. Results

3.1.1. Self-efficacy Achievement of Prospective Biology Teacher Student at UIN Siber Syekh Nurjati Cirebon

To determine the self-efficacy of prospective biology teacher students at the Biology Education Department of UIN Siber Syekh Nurjati Cirebon, a learning model using the TPASK-C Approach was implemented. The TPASK-C Approach was implemented during lectures and practicum activities in the general ecology course over a one-semester period. The results of the self-efficacy measurement of the participants are presented in Figure 2.

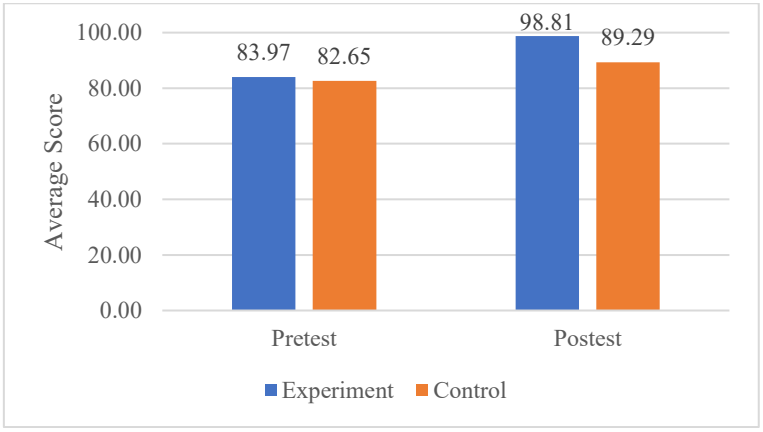

Figure 2. Self-efficacy Achievement of Prospective Biology Teacher Students

The graph reveals a highly significant finding, as both groups, experimental (83.97) and control (82.65), started from very high initial levels of ability and were equal at the pretest. Although both showed improvement on the posttest, the experimental group achieved a near-perfect score (98.81) with a gain score of 14.84 points, which is more than double the control group's 6.64 points increase. The most profound meaning of this data is the extraordinary effectiveness of the treatment, as it was able to produce a significant impact on improvement even in a group with high initial competence, where room for improvement was minimal (approaching a ceiling effect). This strongly suggests that the intervention in the experimental group was successful, as it proved superior in optimizing the potential of participants to achieve a near-maximum level of mastery. To see the achievement of self-efficacy indicators in both classes, see Figure 3.

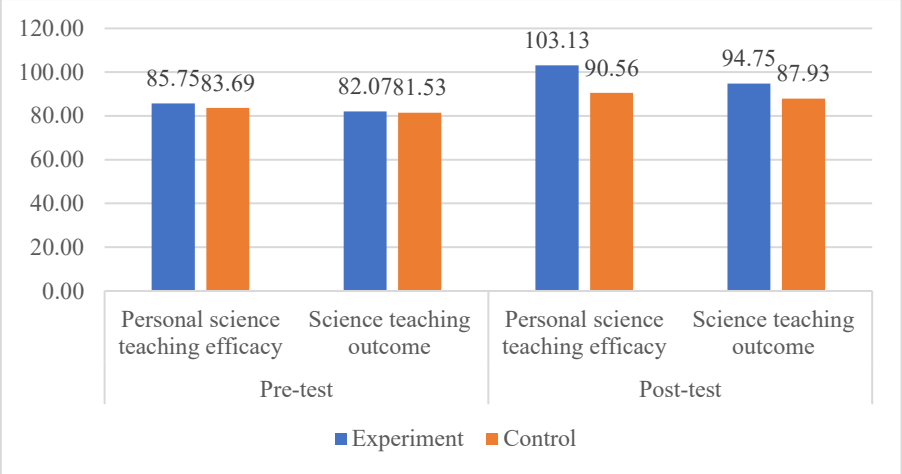

Figure 3. Self-efficacy Indicator Achievement

Figure 3 presents an in-depth comparative analysis of two distinct psychological constructs: personal science teaching efficacy and science teaching outcome. Starting from relatively equal pre-test results for both variables, post-test data indicate that the intervention significantly improved both aspects in the experimental group, far surpassing the control group. However, the more profound significance lies in the differential impact of the treatment: the most dramatic and significant improvement was seen in science teaching self-efficacy, which jumped by 17.38 points in the experimental group, surpassing the 12.68 increase in outcome expectations. This implies that the primary strength of the intervention lies not only in improving general beliefs about teaching outcomes, but also in building teachers' personal self-confidence and belief in their own internal abilities to teach science effectively. To test the scores obtained, a test was conducted, as shown in Table 1.

Table 1. Statistical Test Results of Self-Efficacy Achievement of Prospective Biology Teacher Students

Test	Treatment	Normality Test		Homogeneity Test		t-test
		Sig. Value	Description	Sig. Value	Description	
Pre-test	Experiment	0.059	Normal	0.226	Homogeneous	0.390 (Not Significant)
	Control	0.099				
Post-test	Experiment	0.200	Normal	0.649	Homogenous	0.000 (Significant)
	Control	0.200				

Table 1 presents the results of the prerequisite test, indicating that the data were normally distributed and homogeneous; therefore, the t-test analysis used was valid. The main result shows that at the pre-test stage, there was no significant difference (p=0.390) between the experimental and control groups, confirming that both groups had equivalent initial abilities. In contrast, after the treatment, the post-test results showed a highly statistically significant difference (p = 0.000), which convincingly demonstrates that the treatment given to the experimental group had a real and measurable impact on increasing their self-efficacy compared to the control group.

3.1.2. Research Skills Achievement of Prospective Biology Teacher Student at UIN Siber Syekh Nurjati Cirebon

The implementation of the TPASK-C Approach to practicum work is carried out in lectures and practical work. The TPASK-C practicum work integrates various aspects of technology, pedagogy, and science, packaged contextually to provide comprehensive competencies to prospective biology teachers. The regular model emphasizes the practicum of discovery that is not explicitly linked to the use of technology and pedagogical aspects. To determine the achievement of research skills, results given different treatments (the implementation of the TPASK-C Approach to practicum work and the regular approach are presented in Figure 4).

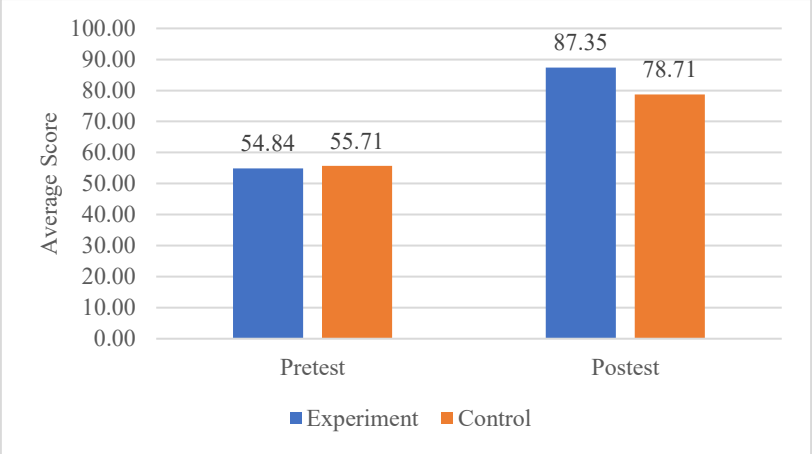

Figure 4. Research Skill Score Achievement

Figure 4 shows the research skills scores achieved in the pre-test and post-test. The pre-test scores indicate that students' abilities at the beginning of the study were similar in both classes. After undergoing treatment using the TPASK-C Approach, the experimental class experienced a more significant increase in scores than the control class, which implemented a regular approach through lecture activities frequently used in daily lectures, such as lectures, discussions, and other assignments. To compare the indicator achievements for each stage of the research in both classes, Figure 5 describes the results.

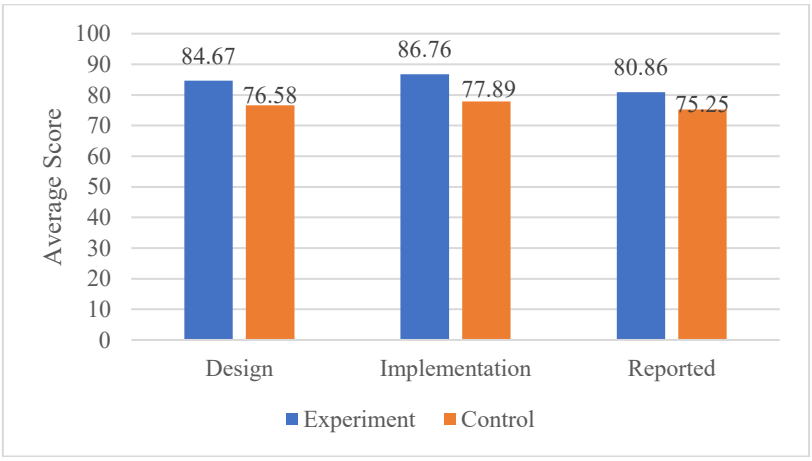

Figure 5. DIR Research Skill Achievement

Figure 5 shows the achievement indicators for the research skills stages, which include the design, implementation, and reporting (DIR) stages. The highest scores were achieved in the implementation stage, followed by the design and reporting stage. The smallest score difference was found in the reporting stage. This suggests that the treatment provided was highly effective in enhancing students' practical skills in designing and implementing research. However, the aspect of reporting research results in writing remains the most significant challenge and the most potential area for improvement in both the experimental and control classes. To find out the research skills achieved, a statistical test was carried out as shown in Table 2 as follows.

Table 2. Research Skills Statistical Test Results

Test	Treatment	Normality Test		Homogeneity Test		t-test
		Sig. Value	Description	Sig. Value	Description	
Pre-test	Experiment	0.157	Normal	0.219	Homogenous	0.613
	Control	0.135				(Not Significant)
Post-test	Experiment	0.200	Normal	0.084	Homogenous	0.000
	Control	0.082				(Significant)

Table 2 shows the research skills test between students in the experimental and control classes. The test results indicate a normally distributed and homogeneous distribution of research data, thereby meeting the assumptions of parametric statistics and t-tests for the pre-test and post-test. The pre-test results indicate that the research skills of students in both classes are not significantly different, and the post-test results show significantly different achievements. It can be concluded that the treatments given statistically have different

impacts. Furthermore, to determine the effectiveness of the implemented TPASK-C approach practicum model, an effect-size test was conducted, as presented in Table 3.

Table 3. Effectiveness of Implementing the Practical Model Using the TPASK-C Approach

Variable	Cohen's d value	Category
Self-efficacy	1.338	Strong (effective)
Research skills	1.469	Strong (effective)

Table 3 shows the effectiveness of the TPASK-C practicum model in improving self-efficacy and research skills. Cohen's d values were 1.338 and 1.469, respectively, indicating a substantial effect on learning using the TPASK-C practicum model. These values indicate that the TPASK-C practicum model is effective in ecology lectures. In other words, the use of the TPASK-C practicum model has proven effective in improving self-efficacy and research skills.

3.2. Discussion

The use of a practicum learning model with the TPASK-C Approach provides a more contextual learning experience for students, thus contributing significantly to the development of self-efficacy and research skills. The results of this study revealed several important findings related to the implementation of the practical model with the TPASK-C Approach in increasing the self-efficacy of prospective biology teachers, namely: the first finding is that the practical model with the TPASK-C Approach has been proven effective in increasing self-efficacy. Self-efficacy is a key factor in the source of human action (human agency), "what people think, believe, and feel influences a person's actions" (Code, 2020; Basileo et al., 2024).

The TPACK-C Approach to practicum work contributes to the development of self-efficacy in prospective biology teachers. This model integrates the use of technology, pedagogical aspects, and scientific knowledge in a real-world context. The implementation of the TPACK-C approach to practicum work significantly increases the self-efficacy of prospective biology teachers, as this model provides students with the opportunity to experience firsthand how to integrate technology, pedagogy, and scientific content in a relevant learning context. According to Nacaroğlu & Göktaş, (2024), self-efficacy directly influences behavior. Furthermore, Maddux, (2002) states that self-efficacy also plays an important role in psychological adjustment, mental and physical health, and the effectiveness of behavior change strategies.

The use of context in learning motivates students because it is relevant to everyday life, thereby fostering self-efficacy. When students successfully apply their knowledge and skills in real-life contexts, they feel more confident in their abilities in science. TPASK-C-based learning is a catalyst for increasing student motivation and self-efficacy. When subject matter is presented in a way that is relevant to everyday life, students not only find deeper meaning but also feel a personal connection that sparks their intrinsic interest. This increased motivation is inherently related to the development of self-efficacy, which is an individual's belief in their ability to succeed at a task or achieve a specific goal. This increased confidence contributes to the development of self-efficacy (Van Dinther et al., 2011; Britner & Pajares, 2006).

The use of technology in implementing the TPASK-C practicum model increases self-efficacy in prospective biology teachers. Self-efficacy is believed to influence teachers' teaching abilities. This finding is consistent with Abbitt, (2011) research, which demonstrates that increasing prospective teachers' knowledge about teaching with technology can enhance their self-efficacy beliefs in using technology efficiently. These results are also in line with (Ertmer et al., 2015), which states that although knowledge of technology is necessary, it is meaningless if teachers lack self-efficacy in using the technology in learning.

Twenty-first-century teachers are expected to master TPACK comprehensively (Chai & Kong, 2017). Based on this review, self-efficacy plays a significant role in determining teacher knowledge in teaching practice and has become a topic of considerable interest in the field of biology teacher education (Menon & Sadler, 2016). The TPASK-C Approach to practicum work provides students with the opportunity to be more trained in the use of technology so that they can develop the competence of science teacher candidates. The implementation of the TPASK-C Approach enables students to utilize technology, develop pedagogical skills, and build knowledge through reading scientific journals, thereby enhancing the motivation and self-efficacy of student teachers (Aydın & Boz, 2010; Wang et al., 2014).

This research was conducted in an ecology course on the topic of environmental factors affecting organisms. During the practicum activities on this material, students' self-efficacy was clearly observed. For example, when students successfully analyzed river water quality data in their environment and related it to ecosystem health (a real-life context), they not only understood the concept of 'eutrophication' in ecology but also felt more confident in their ability to teach complex and relevant environmental issues to their students in the future. A description of the TPASK-C framework in this study is presented in Figure 6.

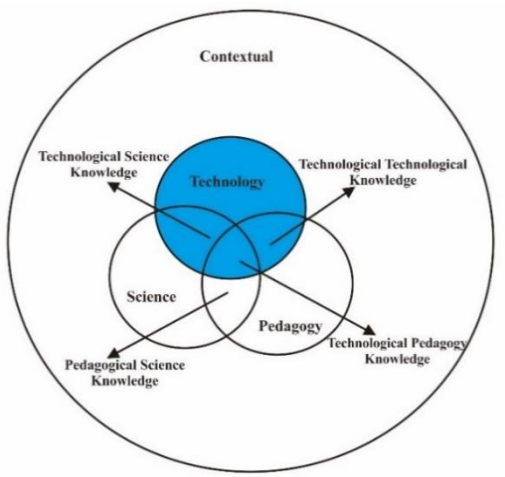

Figure 6. Framework of Technological Pedagogical Science Knowledge and Contextual

Figure 6 shows the TPASK-C (Technological Pedagogical Science Knowledge and Contextual) model, which consists of three main components: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). This model emphasizes the importance of integrating these three components in the learning process. Furthermore, this model also incorporates contextual knowledge (CK), which suggests that learning should be relevant to real-world contexts. The interactions between these components are represented by arrows, indicating reciprocal relationships. The TPASK-C framework complements TPACK by adding the context of science knowledge and real-world situations in learning.

The implementation of the TPASK-C Approach to improve research skills revealed three important findings: the first finding is that increased self-efficacy in research will encourage the development of research skills in prospective biology teacher students. Research skills are part of personal science teaching efficacy, which refers to a teacher's confidence in their ability to teach science effectively. This includes confidence in designing and implementing instruction that motivates students and helps them understand scientific concepts (Loveys et al., 2014). A good understanding of the nature of science (NoS) will encourage more optimal science teaching (Lederman & Lederman, 2004). This level of teaching efficacy influences teachers' teaching practices, classroom management, and interactions with students (Tschannen-Moran & Hoy, 2001). Teachers with high efficacy tend to employ innovative teaching strategies, which can help increase students' interest and understanding of science (Hoy & Spero, 2005).

Second, the findings of this study show that research reporting skills are an area where prospective biology teacher students tend to master less. Several factors were found based on the data obtained from this study, namely: (1) the low writing skills of students, (2) lack of knowledge about scientific publications and publication ethics among students, (3) campus academic culture that has not trained students in scientific publications, (4) students still accustomed to reporting practicum results in the final report format rather than in the form of an article manuscript as required in this research. According to (Willison & O'Regan, 2007), the reporting stage is related to the skills required to implement scientific ethics in publication or research reporting. The results of research conducted by Aripin et al., (2021) confirmed that the reporting stage is an area where students tend to struggle.

Third, the TPASK-C Approach to practicum work in this study was shown to contribute significantly to research skill achievement. These results suggest that the TPASK-C Approach to practicum work and the regular (inquiry) model used in this study both aim to improve scientific understanding but differ in their focus. The TPASK-C Approach to practicum work explicitly integrates technology, pedagogy, scientific knowledge, and real-world contexts (Widowati et al., 2020; Mugot & Fajardo, 2021). Inquiry, on the other hand, focuses on the process of discovery through questions and investigations. The TPASK-C Approach to practicum work emphasizes the integration of technology as a learning tool, while inquiry does not always involve technology (Chai et al., 2013). The TPASK-C Approach to practicum work also emphasizes real-world contexts, connecting learning to student experiences (Constantinou et al., 2018).

The effect size test using Cohen's d test showed that the implementation of the TPASK-C Approach to practicum work was effective in improving self-efficacy and research skills in prospective biology teacher students. The results of this study found several supporting reasons as empirical evidence for these findings, namely, the integration of technology, pedagogy, scientific knowledge, and real-world contexts encouraged the strengthening of students' TPACK aspects. The integration of technology, such as simulations and data analysis, increased students' confidence in using it for learning (Valtonen et al., 2019). Relevant pedagogical approaches, such as guided inquiry, improved conceptual understanding, and teaching skills. Real-world contexts through

case studies or research projects connected theory with practice, strengthening understanding and motivation. The TPASK-C Approach to practicum work also encouraged students to design and implement research, analyze data, and communicate findings, which improved their research skills. The integration of technology facilitated access to resources and analytical tools, supporting the research process (Alghamdi & Altalhab, 2024).

Although the results of this study are significant, they were obtained from a limited set of subjects, specifically one campus and one ecology course, which covered three topics: environmental factors that influence organism performance, community structure influenced by environmental characteristics and abundance, and organism interactions and patterns within communities. Therefore, the results of this study cannot be generalized widely. For further research, correlational testing can be conducted to investigate the specific relationship between self-efficacy and research skills.

4. Conclusion

The results of this study indicate that the TPASK-C practicum model is efficacious in improving the self-efficacy and research skills of prospective biology teachers. This model integrates technology, pedagogy, scientific knowledge, and real-world contexts, providing students with contextual and meaningful learning experiences. Based on these results, it can be concluded that the TPASK-C model has proven effective and can be used as an alternative innovative practicum model. Consequently, this model can be widely applied in LPTK with adaptations according to the context. Further research is needed to explore the effectiveness of the TPASK-C model in other contexts and courses, as well as to examine the factors that influence it. In addition, the development of a more comprehensive assessment instrument is needed to measure the impact of the TPASK-C model on various aspects of prospective biology teacher competency. Overall, this study provides empirical evidence of the potential of the TPASK-C model as an innovative and compelling learning approach to improve the quality of education for prospective biology teachers in Indonesia.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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