Enhancing Prospective Teachers' Professional Competence: A Project-based Learning Approach with the Technological Pedagogical Content Knowledge (Tpack) Model

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Abstract

The presence of skilled and knowledgeable educators who have a profound understanding of scientific and technological subjects can have a significant impact on the quality of education during the industrial revolution era. This study explores the effectiveness of a project-based learning (PBL) approach integrated with the Technological Pedagogical Content Knowledge (TPACK) model in enhancing the professional competence of prospective teachers. The TPACK framework emphasizes the intersection of technological knowledge, pedagogical knowledge, and content knowledge, providing a holistic view of effective teaching practices. The research employs a R and D methods design, involving pre- and post-assessments, and quantitative analysis of participants' experiences. Aspiring educators participate in project-based exercises that are specifically crafted to seamlessly incorporate technology into their instructional approaches, thereby cultivating the growth of TPACK. Results indicate a significant improvement in participants' professional competence, demonstrating the efficacy of the PBL approach within the TPACK framework. Implications for teacher education programs and recommendations for future research are discussed. This study makes a valuable contribution to the ongoing conversation surrounding innovative pedagogical methods for effectively preparing educators to navigate the challenges of today's diverse and dynamic classrooms.

Keywords: *Project based-learning, teacher professional, TPACK model*

Introduction

During the period of the industrial revolution, the quality of education can be significantly impacted by the presence of proficient and knowledgeable educators who possess expertise in scientific and technological subjects. In the process of teaching a concept, teacher innovation and creativity is needed in presenting the material so that misconceptions do not occur. Possessing a strong command of technology is a crucial skill for aspiring educators and current teachers alike. It enables them to effectively convey information in a manner that is accessible and comprehensible to their students. The results of the 2018 PISA (Program for International Student Assessment) survey conducted by the OECD (Organization for Economic Cooperation and Development) showed an increase with the average literacy score of Indonesian students in reading, mathematics and science still low (literacy with a score of 371, score average mathematics with a score of 379, science with a score of 389)(Schleicher, 2019).

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This is also relevant to the TIMSS (Trends in International Mathematics and Science) survey which states that only 5% of students in Indonesia are able to work on high category questions that require reasoning(Martin et al., 2016).

Relevant to the results of the PISA and TIMSS surveys, there is a need to improve the quality of educators to be able to produce output, namely students at the basic education level who are more competent. From the results of interviews conducted with prospective teacher students at PGMI IAIN Lhokseumawe, it was found that the professional abilities of prospective teacher students have not developed well, this can be seen in preparing learning plans, Creating instructional resources that incorporate technology-based learning tools. The findings of previous exploratory investigations that have been conducted regarding the TPACK abilities of prospective teacher students found that students' TPACK abilities in preparing lesson plans have not developed significantly with a hypothesis test value of only 6.2%, however for students' digital literacy abilities it has a positive effect with a value of 77.2 % of The capability to develop instructional strategies and curricula in elementary schools(Fazilla et al., 2022).

Considering the initial issues at hand, it is evident that there is a necessity to enhance the educational standards at elementary schools by placing emphasis on children's experiences.. Apart from mastering technology, educators' ability to choose appropriate learning methods and Models play a crucial role in the development of higher-order thinking skills among students. One of the learning models that is demanded by the curriculum, especially the independent curriculum, is the project-based learning model (PBL). PBL is an instructional approach that engages students in real-world investigations and problem-solving through a systematic inquiry process. Students are presented with authentic inquiries or challenges that require them to apply their knowledge and skills in order to find solutions. By immersing students in these real-life scenarios, PBL promotes critical thinking, collaboration, and problem-solving abilities. This instructional method involves students in hands-on problem-solving and analytical thinking, prompting them to use their knowledge and abilities in a valuable manner.

In research by Duncan et al (2013) it is stated that the presence of teacher assistance for children in implementing the PBL learning model makes it easier for children to create final products, gain knowledge or experience, Enhancing children's techniques and skills while also incorporating values into their development is a crucial aspect of our approach(Duncan et al., 2013). We recognize the significance of integrating principles such as collaboration, efficiency, and time allocation in a pragmatic fashion. According to other studies, it has been found that having strong professional competency among educators when implementing the PBL approach exerts a beneficial impact on student growth and progress. Nevertheless, difficulties occur in regard to the distribution of time during its implementation, which hinders the complete achievement of learning objectives (Ferdinand et al., 2024; Jaleniauskien, 2016).

In its implementation, attention educators and individuals aspiring to be educators, implementing the PBL model in the classroom is not an easy thing, it requires the teacher's commitment and ability to plan projects, especially on science material so that it is relevant to the demands of the current curriculum. The findings of a research study conducted on prospective teachers, which involved students, revealed that equipping teachers with a comprehension of PBL concepts had a significant effect on their classroom management skills. This included their ability to create and execute projects even with limited resources, enhance their literacy skills as educators, and develop a deeper understanding of the social environment

in which children exist(Alrawashdeh et al., 2024). The results of the study found that combining creative teaching with PBL can overcome several challenges during the pandemic to be able to achieve learning goals by motivating and supporting social relationships, especially in science learning that utilizes technology (virtually)(Lin et al., 2021; Miller et al., 2021).

Technological developments in the 21st century require teachers to master technology to be incorporated into the educational framework, in other words not only mastering Pedagogical Content Knowledge (PCK), but teachers must also be able to teach learning material by utilizing technology, this can be done by integrating content and knowledge through the use of appropriate technology by integrating TPACK(Bueno & Niess, 2023; Latip et al., 2023). The TPACK instrument was developed by dividing the TPACK framework into online TPK and offline TPK, resulting in seven dimensions: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge. (TPACK) (Abubakir & Alshaboul, 2023; Schmid et al., 2020)

TPACK has been incorporated into numerous studies, highlighting the vital importance of educators in skill fully choosing suitable resources and technology for educational objectives. Furthermore, the results of the analysis of the teacher's TPACK abilities are better from better aspects, especially in the Early Childhood Education Center, TCK aspects. and TPK(Saengbanchong et al., 2014). Furthermore, Ammentorp et al (2022) Research has indicated that the incorporation of TPACK into learning environments can effectively enhance students' motivation and self-efficacy in the learning process. The utilization of technology enables convenient access to personalized teaching materials, contributing to the enhancement of self-assurance, social aptitude, and effective communication skills in individual learners(Ammentorp et al., 2022).

Professional competency serves as the primary benchmark for teachers and aspiring teachers in effectively incorporating pedagogy, content, and technology into the learning process. The integration of technology and pedagogical methodologies enables the development of critical, systemic, and computational thinking, decision-making, and problem-solving abilities, which are recognized as essential talents for the 21st century(Bariyyah, 2021; Meyer & Norman, 2020). The study findings indicate that implementing the PBL learning model can enhance students' sense of ownership over their learning and motivate them to improve their study habits and develop their skills in research, management, and social interactions. The researchers identified notable disparities in self-efficacy and scores between pre-service teachers who underwent PBL and the control group who did not get PBL(Geitz & Kirschner, 2016; Webb & Moallem, 2016).

The previous researchers have investigated the creation of the TPACK-based PBL learning model, which primarily aims to enhance teacher competency in the context of TPACK to facilitate the acquisition of 21st century skills.(Cheng et al., 2022; Nordin et al., 2016). Furthermore, from the results of previous studies, it was found that the development of the PBL model only focused on The utilization of technology allows for the development of learning tools and foundational teaching skills for student teachers(Raquel & Fernandes, 2014). Therefore, researchers want to conduct research with the aim of developing a TPACK-based PBL paradigm that enhances the professional competency of aspiring teacher students. The formulation in this research is, is the integration of the PBL Model with TPACK is a powerful approach to education feasible for improving the professional competency of aspiring teacher students? and is the PBL Model integrated with TPACK effective in improving the professional

competency of aspiring teacher students? The findings from this research can Contribute to the advancement of knowledge regarding the specific aspects or skills that educators must enhance in order to effectively teach 21st-century skills to students utilizing a PBL approach integrated with TPACK.

Methods

Research Design

The study was conducted utilizing a Research and Development (R&D) methodology comprising of five distinct phases: analysis, design, development, implementation, and evaluation. In the development of the PBL model which is integrated with TPACK, there are several supporting tools that will be used in Natural Science (IPA) material, namely; Semester Learning Plan (RPS), Science Module, and assessment instruments. The next process, before the product is tested with users, is validated by a team of experts consisting of language, material and instructional model experts. After the product is said to be feasible, the next step is to carry out initial trials in small groups. The trial was carried out on 1st semester students who were prospective elementary education teachers. After making revisions from the initial phase of testing, it was continued with a large group of 1st semester students but the participants were different from the initial phase of testing. Results of field trials to determine the effectiveness of the product being developed.

Participants

The sampling technique is purposive sampling because the sampling method is carried out with a specific purpose, where the researcher selects respondents based on certain characteristics or criteria that are considered relevant to the research objectives. Sampling was taken using purposive sampling because the researcher wanted to ensure that the sample selected was relevant to the aim. The total sample was 86 people who were divided into three groups. The expert team consists of four persons, 20 persons for initial stage testing and 62 persons for field testing.

Data Collection Techniques

The method employed to acquire data is through providing the TPACK-based PBL Model book, lecture tools and assessment sheets to experts and practitioners. The next stage is that experts and practitioners give a value to each indicator in the assessment aspect. The assessment of the implementation of learning model syntax, social systems and reaction principles consists of 5 (five) scales, namely; very low (value 1), low (value 2), fair (value 3), high (value 4) and very high (value 5), the questionnaire grid can be seen in table 1.

Table 1. PBL Model Integrated with TPACK Questionnaire Grid and Learning Tools.

No	Aspect	Indicator	Item	Total of Item
1.	Appropriateness	Interesting content	1	5
		Content difficulty level	2	
		Component clarity model	3	
		Clarity of purpose use	4	
		Model relationship with professional abilities Teacher	5	
2.	Presentation	Clarity of model syntax	6	6

No	Aspect	Indicator	Item	Total of Item
		Coherence and sequence of presentation material	7	
		Relevance of tables and figures	8	
		Numbering chaos	9	
		Ease of understanding model through Student Worksheets	10	
		Student Worksheets have been integrated with technology	11	
3.	Language	Grammatical appropriateness	12	4
		Clarity of terms and instructions	13	
		Tasks are easy to understand	14	
		Questions are easy to understand	15	
4.	Layout	Cover appeal	16	2
		Content has been integrated with technology	17	

Data Analysis Technique

The data analysis used in this research is a quantitative descriptive analysis method. The data analyzed in quantitative descriptive analysis were the results of product assessments by material experts, media experts, student response questionnaires, prospective teacher professional ability questionnaires and observation sheets. The data were evaluated using N-gain, which is calculated as the difference between the pre-test score and the post-test score. Gain reflects the increase in professional competence of prospective teacher students after receiving science learning using the TPACK-based PBL model. The normalized gain normalization test (N-gain) can be calculated using the Hake equation (Hake, 2002).

$$N - Gain = \frac{\text{Score of posttest} - \text{Score of pretest}}{\text{Maximu score} - \text{pretest score}} \qquad (1)$$

It is explained that the normalized gain (N-Gain) is G, the maximum (ideal) score is the result of the initial and final trials. N-gain can be classified as in table 2.

Table 2. Interpretation Of N-Gain.

N-Gain	Interpretation
0.00<N-Gain<0.30	Low
0.30≤N-Gain≤0.70	Medium
N-Gain>0.70	High

Results and Discussion

This research produces a PBL integrated with Technological Pedagogical Content TPACK which can improve the professional competence of prospective teacher students to be appropriate and effective. The stages carried out in this development research process were to redesign the PBL model by integrating the TPACK stages in the learning model syntax. The next step is preparing lecture tools that are integrated with PBL on TPACK. Before the resulting product is tested with potential users, it is validated first with a team of experts to produce a product that is suitable for use. The results of the validation test by the expert team are as in table 3.

Table 3. Validation Results from the Expert Team.

No.	Expert Team	Validation Score	Description
1.	Language	5	Proper to use
2.	Instructional Model	4.5	Possible to utilize with simple modifications.
3.	Material	4.5	Possible to utilize with simple modifications.

From table 3 it can be seen that the validation results from language experts obtained a score of 5, which means the PBL model device is suitable for use without revision. Furthermore, validation was also carried out by instructional model experts who obtained a score of 4.5, meaning the model was suitable for use with slight revisions to the resulting model book. Furthermore, the researchers also validated the science material on 2 experts, obtaining an average score of 4.3, meaning that the learning product was suitable for use but needed slight revisions on several tools, namely the science textbooks that would be used by lecturers. So, the average result of the expert assessment was 96.25%.

Furthermore, after the model and tools were validated by a team of experts, the next stage was revised and tested using 1st semester students in science material to see the response to the TPACK integrated PBL model. In the science learning process, students are given science textbooks and student worksheets (LKM) which are integrated with the TPACK-based PBL model. Student response data from small group trials can be seen in table 4.

Table 4. Results of Small Group Trials.

Question Item	Average value	Criteria
1	80	Positive
2	70	Positive
3	80	Positive
4	70	Positive
5	69	Positive
6	70	Positive
7	70	Positive
8	80	Positive
9	90	Very positive
10	80	Positive
11	85	Very positive
12	85	Very positive
13	80	Positive
14	90	Very positive
15	80	Positive
Average value	78.60	

The results obtained in table 4 with 15 questions to 20 first semester The pupils achieved a mean score of 78.60, meaning that the results of the first trial received a positive response from students. Therefore, the outcomes of the TPACK integrated PBL model trial received a positive response from students, both in the model syntax and supporting devices. It can be concluded that the model developed is suitable for use. The resulting product can be tested with a large group. Furthermore, this research also wants to see an increase in the professional competence of prospective teacher students after using the TPACK integrated PBL model with its tools. The results of trials in large groups can be seen in table 5.

Table 5. Results of Large Group Trials.

Respondents	Pre-test Score	Post-test Score	N-Gain	Category
1	38	50	0,92	High
2	46	47	0,20	Medium
3	41	46	0,50	High
4	45	48	0,50	High
5	44	51	1,00	High
6	39	46	0,58	High
7	44	47	0,43	High
8	40	45	0,45	High
9	39	51	1,00	High
10	42	45	0,33	Medium
11	39	44	0,42	Medium
12	48	50	0,67	High
13	38	46	0,62	High
14	40	45	0,45	High
15	39	45	0,50	High
16	38	45	0,54	High
17	46	48	0,40	Medium
18	48	50	0,67	High
19	40	43	0,27	Medium
20	45	48	0,50	High
21	39	44	0,42	Medium
22	38	43	0,38	Medium
23	33	44	0,61	High
24	38	46	0,62	High
25	45	47	0,33	Medium
26	45	47	0,33	Medium
27	39	46	0,58	High
28	46	48	0,40	Medium
29	47	48	0,25	Medium
30	44	46	0,29	Medium
31	45	47	0,33	Medium
32	44	46	0,29	Medium
33	39	45	0,50	High
34	45	48	0,50	High
35	45	47	0,33	Medium
36	43	46	0,38	Medium
37	46	48	0,40	Medium
38	46	48	0,40	Medium
39	39	45	0,50	High
40	44	47	0,43	High
41	41	46	0,50	High
42	42	45	0,33	Medium
43	41	43	0,20	Medium
44	39	45	0,50	High
45	45	48	0,50	High
46	39	43	0,33	Medium
47	49	51	1,00	High
48	39	47	0,67	High
49	46	48	0,40	Medium
50	45	48	0,50	High
51	47	51	1,00	High
52	39	47	0,67	High
53	43	48	0,63	High
54	39	47	0,67	High
55	49	51	1,00	High
56	44	48	0,57	High
57	39	47	0,67	High
58	43	47	0,50	High
59	44	48	0,57	High
60	43	48	0,63	High
61	46	50	0,80	High
62	45	48	0,50	High

Based on table 5, it can be seen that 38 students had professional competency scores in the high category, and 24 students were in the medium category, so the average score was 0.52 or 62% of students already had high professional competency as prospective teachers in basic education and 38% in the medium category, meaning the product produced is Successful in enhancing professional expertise.

This research focuses on looking at improving the professional competence of prospective teacher students in basic education using the TPACK-based PBL model that has been developed by researchers. From the research results, it can be seen that the model that has been developed by researchers, namely the TPACK integrated PBL model, appears suitable for use based on validation from a team of experts. Trial II was carried out by applying the model and supporting tools in science learning for PGMI semester 1 students. Based on student responses to the model, namely model syntax, science textbooks integrated with TPACK and LKM-based Project Based Learning models, it was found that 78.6% of students gave positive responses. Furthermore, after implementing the model, the increase in proficiency level of prospective teacher students was evaluated based on five key indicators. These indicators include their ability to effectively grasp and comprehend subject material, their mastery of fundamental concepts and scientific thinking patterns relevant to the subjects they will be teaching, their capacity to develop creative and innovative instructional strategies, their commitment to professional growth through reflective practices, and their utilization of information and communication technology to enhance self-development., it was found that an average of 62% of students were in the high category.

Regarding the professional competencies formed in students, it was found that the average student was still low in developing creative and innovative subject matter, and developing professionalism by taking reflective action. In order to effectively incorporate pedagogy, content, and technology into the learning process, it is crucial for teachers and aspiring teachers to possess professional competence. By utilizing the PBL model, students' sense of ownership over their learning can be enhanced, thereby motivating them to engage in effective learning and refine their research, management, and skills. Social studies The researchers observed notable disparities in the self-efficacy and accomplishment scores of pre-service teachers who underwent PBL in comparison to the control group who did not partake in PBL(Mahasneh et al., 2021).

It is hoped that the use of the PBL model integrated with TPACK for prospective teacher students can become the main provision for student teacher candidates in improving their professional competence by being Capable of comprehending the subject matter proficiently, preparing learning tools that are relevant to the times and being Capable of enhancing their own quality by not only mastering material content only, but is expected to be able to integrate technology in designing instructional and be able to produce output in the form of meaningful projects for students in elementary schools. Professional competency is the mastery of tips for providing independent guidance and counseling, which is developed and honed through practice in applying academic competencies that have been obtained in an authentic context. These competencies are relevant to broad and in-depth mastery of learning material and are expected to provide learning progress for students (Costes-onishi & Kwek, 2023; Crawford et al., 2020; Geitz & Kirschner, 2016). The use of the PBL model is also seen to be able to improve the professional abilities of prospective teacher students which can be seen from the increase in performance, not only understanding science content but being able to design and complete science projects given by lecturers via worksheets and being able to present them well to other

students. Professional competence can support the process of improving teacher performance in improving the quality of education, optimal teacher work must also be in line with educational goals(Peng et al., 2019; Sangadji et al., 2020).

In several other studies it was found that combining creative teaching with PBL can overcome several challenges during the pandemic to be able to achieve learning goals by motivating and supporting social relationships, especially in science learning that utilizes technology (virtually) (Mazaya, 2019). In a study conducted by Yoon, (2023), it was found that the use of the PBL learning model assisted by mobile learning applications had an effect on teachers' pedagogical competence by increasing teacher performance abilities, apart from that, student motivation was also better compared to students who did not receive the treatment(Yoon, 2023; Zen et al., 2022). Therefore, the research results show that the development of the TPACK integrated PBL model is suitable for use and has received a positive response from student teacher candidates. Apart from that, the use of the TPACK integrated PBL model has a good and significant impact on increasing the professional competence of prospective teacher students in basic education.

Conclusion

The integration of PBL within the framework of the TPACK model has proven to be a valuable approach in enhancing the professional competence of prospective teachers. Through this innovative combination, our study has uncovered several key findings that contribute to the field of teacher education. The project-based learning environment has provided prospective teachers with hands-on experiences, fostering a deeper understanding of both content knowledge and effective pedagogical strategies. This immersive approach not only engages learners but also encourages the development of critical thinking, problem-solving skills, and collaborative teamwork – essential attributes for 21st-century educators.

The incorporation of the TPACK model has successfully bridged the gap between technology, pedagogy, and content knowledge. Prospective teachers have demonstrated an increased ability to seamlessly integrate technology into their teaching practices, ensuring a more dynamic and effective learning experience for their future students. The model's emphasis on the intersection of these three domains has proven instrumental in shaping well-rounded and technologically competent educators. Moreover, the positive impact on the development of technological, pedagogical, and content knowledge has been evident in the improvement of lesson planning, instructional strategies, and overall teaching effectiveness. Prospective teachers who engaged in the PBL approach with the TPACK model reported a higher level of confidence and preparedness for the challenges they may face in real classroom settings.

Despite these promising outcomes, it is essential to acknowledge certain limitations and areas for future research. Long-term studies tracking the sustained impact of this approach on teachers' professional development, as well as investigations into its adaptability across diverse educational contexts, will contribute to a more comprehensive understanding of its potential. Our project underscores the importance of innovative pedagogical approaches, particularly those integrating PBL and the TPACK model, in preparing prospective teachers for the demands of modern classrooms. As we continue to evolve in the digital age, investing in such strategies becomes imperative for cultivating a generation of educators equipped with the skills and knowledge necessary to navigate the complexities of contemporary education.

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