Effectiveness of the 5E Learning Cycle and Problem-Based Learning in Writing Scientific Article Based on TPACK

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Abstract: This study investigated the effectiveness of incorporating the 5E learning cycle model and problem-based learning (PBL) to enhance students' scientific article writing skills. The study included 58 participants from Universitas Asahan, employing pre-test and post-test group designs. This study utilized descriptive and experimental research methods to analyze the data. Results indicated that classes that implemented the Technological Pedagogical Content Knowledge/TPACK-based 5E-PBL learning cycle model attained an average score of 86.03, while classes that did not integrate this model achieved an average score of 76.81. Significantly higher mean scores were observed among students exposed to the experimental condition. The normality test results indicated that $L_{count} < L_{table}$, where the p-value was > 0.05, validating the normal distribution of data for both experimental and control groups. Additionally, the homogeneity test revealed that $F_{count} < F_{table}$, demonstrating sample homogeneity. The findings support the effectiveness of the TPACK-based 5E-PBL learning cycle model in improving students' scientific article writing abilities.

Keywords: 5E Model, Problem-Based Learning, TPACK

1. Introduction

Scientific papers should emphasize providing direct experience to develop students' abilities in academic writing. One of the most critical factors in enhancing students' academic writing is ensuring they understand what good writing entails, which is best achieved by engaging them in critical thinking throughout the process (Hall, 2017; Quitadamo & Kurtz, 2007; Rohayati & Friatin, 2021). In writing scientific articles, critical thinking is essential to obtain logical answers to the problems being addressed. Writing skills are productive written language skills that enable students to produce written work. Moreover, writing is a complex activity requiring several abilities, including thinking critically and logically, expressing thoughts or ideas clearly, using persuasive language, and applying written rules correctly (Deane et al., 2008). Writing is essential; writing skills must be trained and developed through the learning process. In addition, the learning process should motivate students to be active and productive, creating a pleasant atmosphere.

Proficiency in writing scientific articles is crucial for undergraduate students as it helps them develop a scientific culture (Machmud, 2016). In addition to acquiring knowledge, students should be encouraged to create new knowledge. By publishing scientific articles, students can disseminate

information gathered from research findings, which helps advance their knowledge. In this way, writing scientific articles helps students to stay up-to-date with the latest research in their fields of study. Furthermore, it enables them to refine their research methods and enhance their critical thinking skills, essential for academic success and beyond. Thus, the ability to write scientific articles is a valuable skill for students to acquire during their undergraduate studies.

Scientific papers serve multiple purposes, including the dissemination of knowledge to academic institutions, the development of essential research skills, the demonstration of students' potential and scientific insights in addressing field-related issues, the fostering of a scientific mindset among students, and the provision of a platform for expressing research ideas and findings (Cargill & O'Connor, 2021). Proficiency in scientific writing can contribute to the enhancement of students' communication skills (Lu et al., 2019), critical thinking, and analytical abilities (Walsh et al., 2020). To improve their ability to write precise and accurate scientific papers, students should approach the task with meticulousness, attentiveness, and thoroughness (Tullu, 2019).

It is recommended that students include all or some of their research findings in scientific publications, presented in the form of a scientific article format (Rusliana, 2022). This approach aims to enhance students' critical thinking skills and promote information sharing with the broader scientific community while ensuring that research results benefit society. If research findings are not published, they will not be accessible to or usable by others. However, students need to adhere to the specific formatting requirements of the intended journal when writing scientific articles. Generally, the scientific article format includes a title, author names and affiliations, keywords, abstract, introduction, results and discussion, conclusion, and bibliography (Scholz, 2022).

In academic writing, students often encounter challenges that hinder their scientific articles' quality. To produce a well-written paper, it is essential to consider several aspects, including writing style (Franco et al., 2021; Hasanuddin et al., 2019), research topics (Adelia et al., 2018), literature and empirical data (Aisiah & Firza, 2018), the use of paraphrased quotations (Agathokleous, 2022; Chen, 2021; Hafiar et al., 2019), and proper referencing (Goyal et al., 2020). Unfortunately, many students face difficulties in mastering these skills and producing high-quality scientific articles. Furthermore, finding relevant scientific articles that align with their research interests is also a significant challenge for many students (Tang et al., 2021). This can be attributed to the vast amount of information available, which can be overwhelming, and students may struggle to identify the most relevant sources. Consequently, they may not have access to the most recent and relevant research findings, which can negatively affect the quality of their scientific articles.

To effectively address these challenges, it is crucial for students to actively cultivate their academic writing skills. This includes gaining a comprehensive understanding of the structure and style commonly employed in scientific articles, selecting pertinent research topics, critically evaluating literature and data, and ensuring accurate citation of sources. Moreover, students should make effective use of diverse online databases and search engines to locate relevant and current scientific articles within their field of interest. By acquiring proficiency in these areas and harnessing available resources adeptly, students can elevate the caliber of their scientific articles and augment their overall academic performance.

Developing the capacity of students to write scientific articles is crucial, as they are potential assets for producing research publications in tertiary institutions. Several research studies have been carried out to improve student scientific article writing. One practical approach is by teaching peer editing (Guilford, 2001), which involves (1) getting students accustomed to writing in an organized manner to produce effective writing (Kurniadi, 2017); (2) developing teaching materials specifically for writing scientific articles (Thamrin, 2015); (3) training students to use a bibliography writing application (Anjali & Istiqomah, 2020); (4) using a collaborative approach (Riyanti, 2022); and (5) developing research writing learning models (Nurmasitah et al., 2017). To produce scientific articles without obstacles, one should start by exploring ideas, making observations, analyzing problems, and finding relevant references.

The problem-based learning (PBL) model, which involves presenting problems to students to stimulate their focus and engagement, is a practical approach to teaching students how to write scientific articles (An Nisa, 2018; Sari et al., 2021). PBL is widely utilized in higher education due to its ability to improve students' critical thinking skills (Hine, 2006). Similarly, the 5E learning cycle model (Engagement, Exploration, Explanation, Extension, and Evaluation) has been found to enhance

students' critical thinking abilities (Cahyarini et al., 2016; Ramdani et al., 2021; Suwito et al., 2020). When PBL is combined with the 5E learning cycle, it can lead to increased self-efficacy, critical thinking, learning attitudes, and satisfaction (Jun et al., 2013). Additionally, learning the 5E cycle has been shown to enhance students' learning motivation (Putra et al., 2018). The integration of technology within the 5E learning cycle can further enhance students' interest in learning (Liu et al., 2009).

Technological Pedagogical Content Knowledge (TPACK) learning has been proven to improve the quality of learning for educators and students at the junior high school and university levels (Chai et al., 2020). This framework is established Koehler and Mishra (2009) and is built upon Shulman's (1986) concept of Pedagogical Content Knowledge (PCK). TPACK emphasizes the integration of technology with pedagogy and content knowledge, suggesting that effective technology integration for teaching specific content requires understanding the relationships between these three components. Koehler and Mishra's (2009) framework asserts that teachers need to develop skills and knowledge across three main areas: content (C), pedagogy (P), and technology (T), along with an understanding of the interactions between these components, represented as Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Pedagogical Content Knowledge (PCK) (see Figure 1).

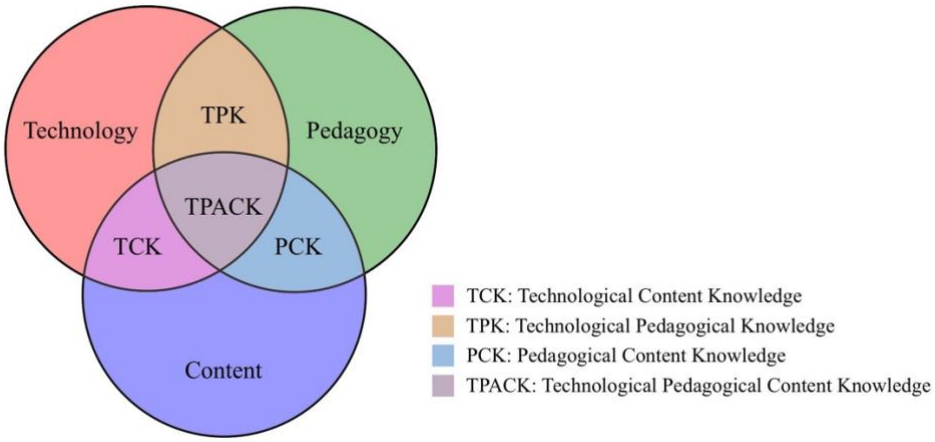

Fig. 1 TPACK Framework

The use of technology in teaching should not only be conceptual but should also be applied directly (Tanak, 2020). TPACK prepares the learning environment for complex interactions between technology, pedagogy, and subject matter knowledge. It promotes innovation and renovation of 21st-century teaching practices that align with the current era of Society 5.0 (Goradia, 2018). However, some studies have found deficiencies in the TPACK learning framework. Some educators and students are still not familiar with using technology (Fuada et al., 2020). To address this issue, researchers have developed a guidebook that can provide a step-by-step process of using technology in learning. The 5E learning cycle is proposed as a solution to overcome the problems in TPACK learning. Figure 2 illustrates the integration of the TPACK and PBL approaches within the 5E learning cycle. This combination has developed a new model wherein each stage of the 5E learning cycle is supported by the PBL approach and TPACK components. For example, in the Engage stage, the role of the PBL approach is to assist in the introduction of the problem, while TPACK supports the integration of interactive technology. Combining the TPACK-based 5E-PBL learning cycle model allows students to find creative solutions to technical and substance-related problems in writing scientific articles. Therefore, developing a TPACK-based 5E-PBL learning cycle model is necessary to enhance students' scientific article writing skills.

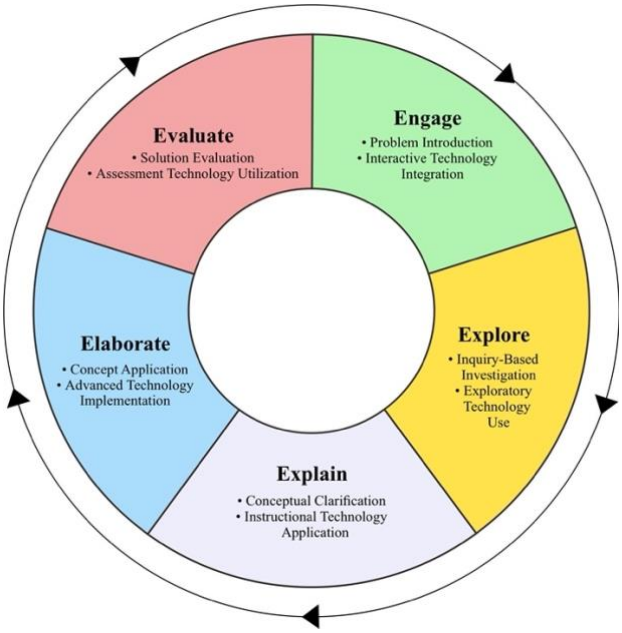

Fig. 2 TPACK-Based 5E-PBL Learning Cycle Model

Previous studies have focused on enhancing proficiency in writing scientific articles, but none have yet developed a TPACK-based 5E-PBL learning cycle model. It is an intriguing area of research to combine these two models and approaches into a single learning model. This combination will result in a new syntax that incorporates technology at each stage of the designed model. Given the growing demand for innovative learning methods that effectively utilize technology, this study aims to develop a unique TPACK-based 5E-PBL learning cycle model. While previous research has explored the relationships between TPACK learning and the 5E learning cycle (Mustafa, 2016), the 5E learning cycle and PBL (Jun et al., 2013), and TPACK and PBL (Kamid et al., 2021), none have investigated all three simultaneously and their connection to scientific article writing. Figure 3 illustrates the proposed model in relation to students' scientific article writing ability. Each stage of the 5E learning process, supported by TPACK and PBL, influences the students' skill in writing scientific articles.

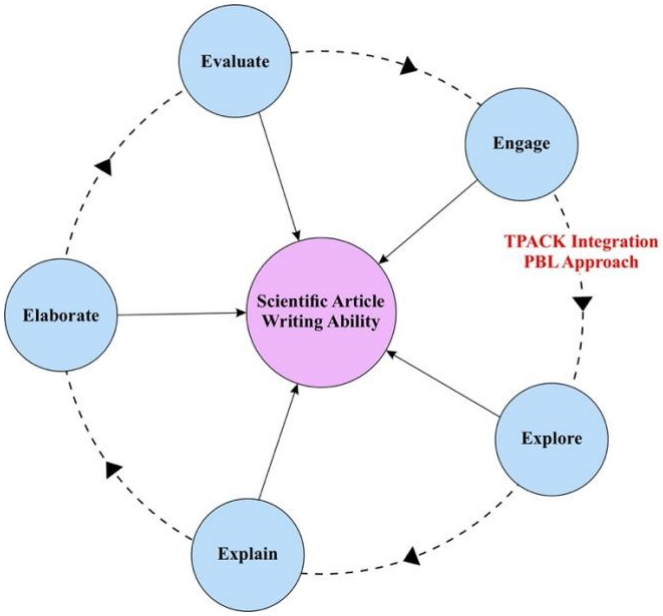

Fig. 3 Correlation Between the Model and Students' Scientific Article Writing Abilities

Therefore, the research questions for this study are as follows: (1) how do students engage in writing scientific articles using the TPACK-based 5E-PBL learning cycle model, (2) what is the level of

proficiency in writing scientific papers attained through the 5E-PBL learning cycle model; and (3) is the 5E-PBL learning cycle model a practical approach to learning scientific writing for undergraduate students? The next section discusses the methodology.

2. Methodology

The effectiveness of the TPACK-based 5E-PBL learning cycle model was analyzed using experimental research. The sample for this study consisted of 58 students from different faculties at Universitas Asahan who were in their second semester. Most students stated that they had never learned how to write scientific articles. The 5E learning cycle model and PBL were utilized to improve students' ability to write scientific articles. The average age of the students was 20 years old. Pre-tests were conducted at the beginning of the course to control for the testing effect. During these pre-tests, the students were asked to create a scientific article based on their understanding. The study lasted six weeks, and the data were analyzed using SPSS 20. The students' writing scores were assessed based on their average scores. The scientific article writing test (performance test) was used as the measuring tool for this research. The completeness of each student was measured based on individual completeness obtained by the students, and Equation (1) was used to calculate the final score.

$$Final\ score = \frac{gain\ score}{maximum\ score} \times 100\% \quad (1)$$

After getting the final score, it is then adjusted according to the criteria used to assess student learning outcomes. The criteria for assessing student learning outcomes are provided in Table 1. To ensure the validity of the TPACK-based 5E-PBL learning cycle model, a normality test, a homogeneity test for the variance of the two data groups, and a hypothesis test were conducted before testing its effectiveness.

Table 1. Assessment Categories for Learning Outcomes Effectiveness

Achievement Level (%)	Category
81 – 100	Excellent
61 – 80	Good
41 – 60	Adequate
21 – 40	Limited
0 – 20	Poor

Note: Adapted from Riduwan (2007)

3. Findings

3.1 Observation Results

Student activities during the learning activities were observed using the "Observing Student Activity" instrument, adapted from Nisak and Sari (2013). The observations were conducted at each meeting, from the first until the last. The results of the six meetings were averaged to generalize the observations of student activities. This study used the TPACK-based 5E-PBL learning cycle model to observe student activities. The activities that were observed included: identifying problems encountered while writing scientific articles, discussing and sharing technical information in groups to solve the problems, conducting group studies related to problems that must be solved using technology, explaining the use of technology, using technology to write scientific articles, and responding to the technology used. The results of student activity observations are presented in Table 2.

Table 2. Observation Results

Observed Activities	Mean Scores (%)	Category
Students mention the problems they encounter when writing scientific articles.	88	Very High
Students discuss in groups and share technical information that can be used to solve the problems they encounter when writing scientific articles.	88	Very High
Students conduct studies in groups related to problems that can be solved by utilizing digital technology.	75	High
Students explain the technology they used.	75	High
Students use recommended technology while writing scientific articles.	100	Very High
Students provide feedback on the technology they have used.	100	Very High
Average Score	**88**	**Very High**

Based on Table 2, the student activity level in the TPACK-based 5E-PBL learning cycle is very high. The high category is shown in activities such as conducting group studies related to problems that require digital technology utilization and explaining the use of technology. On the other hand, students are also highly engaged in activities such as identifying problems encountered when writing scientific articles, discussing and sharing technical information to solve those problems, utilizing recommended techniques in writing scientific articles, and providing feedback on the technology used. The results of student activity observations for the six aspects of learning activities demonstrate that, overall, their engagement during learning activities falls under the very high category.

3.2 Assessment of Writing Scientific Articles

Students were assessed individually using a scientific article writing test (performance test) developed by Yanti et al. (2018), which served as the measuring tool for the research. The completeness of each student was measured based on the individual completeness they achieved. The data on the results of the student's ability to write scientific articles is presented in Figure 4 .

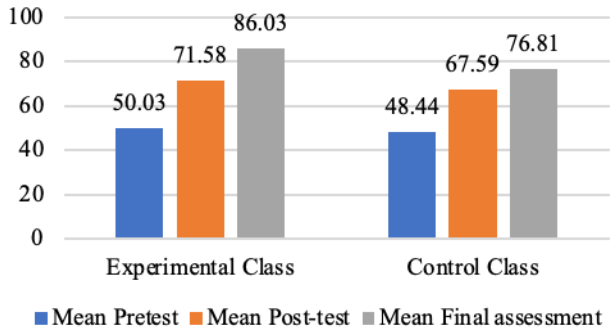

Fig. 4 Assessment Results on Students' Writing Scientific Article Skills

The results of the student's ability to write scientific articles were obtained by observing their performance when writing scientific articles using the TPACK-based 5E-PBL learning cycle. The ability to write articles of Asahan University students who used the TPACK-based 5E-PBL learning cycle model showed that the average score of the experimental class in the pre-test was 50.03, and in the post-test, it was 71.58. Whereas, for the class that did not use the TPACK-based 5E-PBL model, the average score in the pre-test of the control class was 48.44, and in the post-test, it was 67.59. Overall, the writing results of the experimental class students reached 86.03, while the writing results in the control class obtained an average score of 76.81.

3.3 Effectiveness of the TPACK-Based 5E-PBL Learning Cycle Model

Table 3 displays the normality tests on the pre-test and post-test data collected from the control and experimental classes. The findings indicate that the data followed a normal distribution.

Table 3. Normality Test Results of Students' Ability to Writing Scientific Articles

Test	Class	N	Mean	p-value*	Remark
Pre-test	Experiment (A1)	31	50.03	0.050	Normal
	Control (B1)	27	48.44	0.060	Normal
Post-test	Experiment (A2)	31	71.58	0.132	Normal
	Control (B2)	27	67.59	0.200	Normal

Note: *Significance level of 0.05

In this study, one of the prerequisite tests is to check the homogeneity of variance. The results of this test on the data related to skill achievement in writing scientific articles for both the experimental and control classes are presented in Table 4.

Table 4. Results of the Homogeneity Test on Students' Ability to Writing Scientific Articles

	Experimental Class		Control Class		Summary of Analysis Results	
	Pre-test (A1)	Post-test (A2)	Pre-test (B1)	Post-test (B2)	Experimental Class (A)	Control Class (B)
Total	1551	2219	1308	1825	2667	2074
Average	50.03	71.58	48.44	67.59	86.03	76.81
Minimum	33	59	33	55	78	70
Maximum	70	85	63	78	96	89
Standard Deviation	9.464	7.316	8.294	6.008	4.799	5.000
Variance	89.566	53.518	68.795	36.097	23.032	25.003
F_{count}	1.67		1.91		1.09	
F_{table}	1.84		1.93		1.90	
Remark	Homogeneous		Homogeneous		Homogeneous	

Table 4 shows that the experimental and control classes' pre-test and post-test groups and the analysis results' recapitulation show Fcount < Ftable. These results indicate that the data for all groups from the experimental and control classes have a homogenous data distribution with a significance level of 5%.

Based on the normality test and homogeneity of variance results, the data on skills in writing scientific articles were analyzed using a paired samples t-test. The results of the t-test analysis of scientific article writing skills are presented in Table 5.

Table 5. T-test Results (Paired Samples Test) of the Student Ability in Writing Scientific Articles

	Paired Differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1	Pretest-Post-test of the Experimental Class	21.548	4.040	0.726	-23.030	-29.696	30	0.000
Pair 2	Pretest-Post-test of the Control Class	19.148	5.875	1.131	-21.472	-16.936	26	0.000

Based on Table 5, the t-test analysis (paired samples test) shows differences in the average scores of the experimental and control classes. The TPACK-based 5E-PBL learning model significantly affects students' scientific article writing skills. Pair 1 of the output (sig. 0.000 < 0.05) indicates a difference in the average scores between the pre-test and post-test of the experimental class using the 5E-PBL learning model based on TPACK. Pair 2 of the output (sig. 0.000 < 0.05) indicates a difference in the average scores between the pre-test and post-test of the control class using the conventional learning model.

In conclusion, the TPACK-based 5E-PBL learning model significantly influences students' writing skills in scientific article writing. Table 6 provides further details on the average scores of students' writing skills before and after using the TPACK-based 5E-PBL learning model.

Table 6. Descriptive Statistics of Paired Samples for Student Ability in Writing Scientific Articles

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test of the Experimental Class	50.03	31	9.464	1.700
	Post-test of the Experimental Class	71.58	31	7.316	1.314
Pair 2	Pre-test of the Control Class	48.44	27	8.294	1.596
	Post-test of the Control Class	67.59	27	6.008	1.156

4. Discussion

Research has highlighted the challenges that students commonly encounter when writing scientific articles. Nevertheless, there are several practical strategies that can be integrated into the learning process to assist students in overcoming these challenges. One effective strategy is to facilitate group discussions, where students can exchange information regarding technology tools and resources that are recommended for scientific writing. By utilizing these recommended technologies and actively participating in discussions, students can enhance their scientific writing skills. Additionally, providing feedback to students and encouraging them to respond to it can further contribute to their improvement in scientific writing (Horstmanshof & Brownie, 2013).

The TPACK-based 5E-PBL learning cycle model provides a valuable framework for incorporating strategies to improve scientific article writing. Students become more engaged and active learners by integrating group discussions, recommended technologies, and feedback into this model (Freeman et al., 2014). Furthermore, problem-based learning, a vital component of the TPACK-based 5E-PBL learning cycle model, has been found to enhance students' critical thinking skills and writing abilities (Dawilai et al., 2017; Quitadamo & Kurtz, 2007; Yamin et al., 2023).

Empirical evidence supports the effectiveness of the TPACK-based 5E-PBL learning cycle model in improving students' scientific writing skills. This current study found that the TPACK-based 5E-PBL learning cycle model produced higher average values of writing scientific articles compared to a conventional model. In other words, these findings suggest that the TPACK-based 5E-PBL learning cycle model is a convenient resource for improving students' scientific writing skills in education.

Writing scientific articles requires various skills, knowledge, and monitoring procedures (Trapman et al., 2018). To improve students' problem-solving skills in academic writing, studies have shown that problem-based learning (Aslan, 2021; Mccrum, 2016; Palupi et al., 2020) and the 5E cycle learning model (Bakri & Adnan, 2021; Cakır, 2017) are practical approaches. The TPACK-based 5E-PBL learning cycle model incorporates both approaches to enhance students' academic writing skills. By integrating group discussions within this model, students can engage in problem-solving activities and gather information on using technology in scientific writing.

The TPACK-based 5E-PBL learning cycle model provides a valuable framework for incorporating effective strategies into the learning process of scientific writing. One such strategy is group discussions, which emphasizes a self-learning experience for students to obtain information and solve problems related to writing scientific articles. Information gathering is done at each meeting, and the positive results obtained from student assessments show the effectiveness of this model in preparing students to obtain the necessary knowledge and skills to write scientific articles. For example, based on the results of student assessments, experimental class students had an excellent category. These findings

suggest that the TPACK-based 5E-PBL learning cycle model, which combines problem-based learning and group discussions, is a promising approach for improving students' academic writing skills.

The positive results of the TPACK-based 5E-PBL learning cycle model are reflected in students' ability to write scientific articles. Specifically, in Indonesian language courses, the application of this model has been found to positively affect students' writing abilities. The model emphasizes a self-learning experience through group discussions, where students can obtain information and solve problems related to scientific writing. By integrating problem-based learning and group discussions into the learning process, students become more engaged and active learners, which has been shown to increase their success rates in future classes.

In conclusion, writing scientific articles can be a challenging task for students, but there are effective strategies that can be incorporated into the learning process to help them overcome these challenges. The positive results obtained from student assessments highlight the effectiveness of the TPACK-based 5E-PBL learning cycle model in preparing students to obtain the necessary knowledge and skills to write scientific articles. Overall, this model provides a promising approach for improving students' academic writing skills, and its effectiveness has been demonstrated through positive student assessments. Therefore, this model can be a highly effective resource for learning how to write scientific articles in various contexts.

5. Conclusion

The study observed students' writing performance in writing scientific articles using the TPACK-based 5E-PBL learning cycle. The results showed that the average score of experimental class students increased from 50.03 to 71.58, while the control class increased from 48.44 to 67.59 (pre-test to post-test). The TPACK-based 5E-PBL model was more effective in building students' scientific writing skills, with the experimental class scoring an average of 86.03 compared to 76.81 in the control class. Additionally, the model was highly effective in promoting student engagement and activity in the learning process. Therefore, the TPACK-based 5E-PBL learning cycle is a promising approach for improving students' scientific writing skills.Therefore, the TPACK-based 5E-PBL learning cycle model presents a promising approach for packaging learning to write scientific articles in Indonesian language subjects. Future researchers can conduct similar studies at various tertiary institutions based on their respective fields of study. To develop effective learning models, digital media can be used, as the TPACK-based 5E-PBL learning cycle model indirectly facilitates the teaching of knowledge, attitudes, and skills. Further research in this area can contribute to a better understanding of how this model can be optimized and tailored to suit different educational contexts, leading to improved student academic writing skills.

6. Co-Author Contribution

Author 1 conceptualized the research design, developed the methodology, and conducted the investigation. Author 2 supervised the study, interpreted the data, and wrote the manuscript. Author 3 visualized the data, provided resources, and revised the manuscript.

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