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Analysis Implementation of The TPACK Approach by High School Chemistry Teachers

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ABSTRACT
The aim of this research is to study the TPACK skills of chemistry teachers at state high schools in Bengkulu City. The questionnaire results showed that all aspects of TPACK were in the excellent category (mean 85.96%). However, the results of the observations were lower than expected overall, particularly for TK, TCK, and TPACK aspects, which were still considered fair to good. This signals a disconnect between teacher beliefs and the in-class execution. Supporting factors for TPACK implementation include school support, facilities, and teacher motivation, while hindering factors include limited student device ownership, limited internet connectivity, and limited learning time. Therefore, the application of TPACK by chemistry teachers is well implemented but could be further improved by creating technology that is more consistent across learning activities.
Keywords: Chemistry teachers, State Senior High Schools, TPACK

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INTRODUCTION

The Industrial Revolution 4.0 demands that teachers serve as learning leaders, which requires technological innovation. During the Industrial Revolution 4.0, teachers should never stand still but rather want to move forward and adapt. The challenge is to maintain effective learning into the future, and educators need to step outside their comfort zone when it comes to digital inclusion. Students are required to be provided with 21st-century skills that include critical thinking, problem-solving, creativity and innovation, communication and collaboration, as well as digital literacy (Lubis, 2019; Misbah et al., 2022; Saputri et al., 2021; Suyidno et al., 2020; Yani et al., 2021). The integration of information and communication technology (ICT) in the learning process has therefore become inevitable to meet these demands. ICT usage allows learning to be interactive and flexible. Yet, at the same time, it poses many challenges in terms of infrastructure capabilities and resources (e.g., teacher preparedness and the availability of suitable digital learning content), which remain significant barriers to implementation (Hidayatullah et al., 2023).

To meet these challenges, teachers must have competencies that go beyond CR-CK-PK (mastery of subject matter and learning strategies) to include TK (the ability to utilize technology). These three aspects are summarized in the Technological Pedagogical and Content Knowledge (TPACK) framework, which is an important foundation for designing and implementing innovative learning that is in line with the times (Hayati, 2022; Jibril & Adedokun-Shittu, 2024).

The TPACK approach is highly relevant to chemistry learning, especially at the public high school/MA level. Chemistry contains abstract and complex concepts, such as atomic structure, chemical bonds, and thermochemistry, which require a contextual and visual learning approach

(Andriani, 2023). The use of technology, such as simulations, animations, and virtual laboratories, greatly helps students understand these concepts, so the mastery and implementation of TPACK by chemistry teachers are crucial.

An initial overview of the implementation of TPACK in chemistry learning, particularly in pedagogy, content, and technology, was conducted through interviews with several high school chemistry teachers and students in Bengkulu City. The results of these interviews provided the initial basis for examining classroom learning practices and students' perceptions of the effectiveness of teachers' approaches.

The first aspect is pedagogy, which involves understanding the processes and strategies of learning. Based on the initial interview with one of the chemistry teachers, it was found that teachers try to gauge students' readiness to learn by asking probing questions and checking prerequisites at the beginning of the lesson. The strategies used tend to be lectures and discussions. Meanwhile, students noted that the teacher's teaching methods were quite varied; the teacher used lectures and discussions more often, but also conducted experiments.

In terms of content mastery, teachers reported a good understanding of the chemistry material, but faced challenges simplifying abstract concepts, so they were easy for students to understand. This was reinforced by several students' responses, who stated that the teacher's explanations were sometimes confusing and did not emphasize the core concepts. Meanwhile, in terms of technology, teachers recognize the importance of utilizing digital media to support student understanding, especially of abstract concepts. Teachers also reported that technology use remains limited to PowerPoint and YouTube. Teachers revealed that students responded positively to the use of technology, especially when presented visually and interactively.

These findings indicate that the implementation of TPACK by chemistry teachers continues to face various obstacles across pedagogy, content, and technology. Based on these conditions, an in-depth study is needed to determine the extent to which chemistry teachers in public high schools/MA in Bengkulu City implement the TPACK approach in learning. This study aims to measure and describe the implementation of the TPACK approach and the factors that influence its success in chemistry teaching in public high schools/MA in Bengkulu City. The focus of this research involved public high school/MA chemistry teachers in Bengkulu City who taught grade XI, had at least 5 years of experience, and were certified. The purpose of this study was to analyze the implementation of the TPACK approach and the factors that influenced it.

METHODS

This research uses a descriptive qualitative approach with a phenomenological type to describe in depth the implementation of TPACK by grade XI chemistry teachers in public high schools/MA throughout Bengkulu City.

The sample in this research consists of chemistry teachers in public high schools/MA in Bengkulu City who were selected using purposive sampling, with the criterion of having at least 5 years of teaching experience and teaching grade XI. The sample in this study consisted of high school chemistry teachers in Bengkulu City who were selected using purposive sampling, with the criteria of having at least 5 years of teaching experience, teaching grade XI, and being certified.

Data collection was conducted through questionnaires, interviews, and observations. Questionnaires were used to provide an initial overview of the chemistry teachers' level of understanding. In-depth interviews were conducted with selected informants to explore their experiences, strategies, and obstacles in implementing TPACK. Three observers conducted observations during the learning process to assess the implementation of TPACK.

This study began with preliminary interviews to obtain an overview of the use of technology, learning methods, and strategies, and the challenges faced by chemistry teachers in the learning process. Based on the results of these initial interviews, the researchers then developed research instruments in the form of questionnaires, interview guidelines, and observation sheets, which were then validated by experts. The next stage involved distributing questionnaires to all chemistry teachers at public high schools/MA throughout Bengkulu City. The research subjects were selected using purposive sampling. Further data collection was conducted through in-depth interviews and classroom observation to obtain a comprehensive picture of TPACK implementation.

The data obtained from the questionnaire, interviews, and observations were analyzed using the model developed by Miles et al. (2014), which consists of three stages: data reduction, data presentation, and conclusion drawing.

a. Data Reduction

In the data reduction stage, quantitative data from the questionnaire were processed by calculating the average score for each statement across each TPACK aspect. The average question scores and data for each TPACK aspect were converted to percentages. The percentages obtained were then interpreted in the intervals in Table 1.

Table 1. Questionnaire and Observation Interpretation Criteria

Value Interval (%)	**Criteria**
81-100	Very Good
61-80	Good
41-60	Fair
21-40	Poor
0-20	Very Poor

Source: Riduan (2010)

b. Data Presentation

The reduced data is presented in the form of percentage tables and descriptive narratives to describe the level of implementation of TPACK aspects (TK, PK, CK, TCK, TPK, PCK, and TPACK) by chemistry teachers.

c. Drawing Conclusions

The final stage is drawing conclusions and verifying them based on all the data analyzed. To maintain data validity, source and technique triangulation techniques are used, namely by comparing data from questionnaires, interviews, and observations during the learning process.

RESULT AND DISCUSSION

The research began with the distribution of questionnaires to 48 high school/MA chemistry teachers in Bengkulu.

Questionnaire results

The results of the questionnaire score recapitulation for 48 respondents are shown in Figure 1.

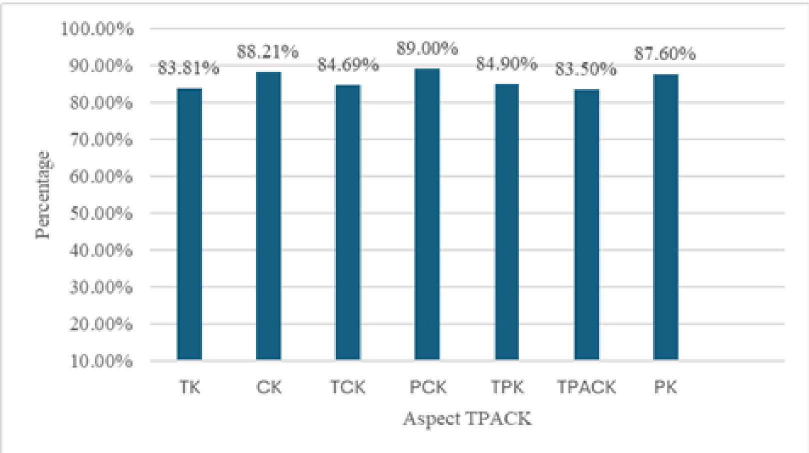

Figure 1 Average Questionnaire Recapitulation Results

Interview results

The details and main points from the interview results have been summarized and presented in Table 2.

Table 2 Interview Results

Aspect	Summary of interview results
TK	• The majority of teachers use mobile phones, PowerPoint, YouTube videos, and projectors during lessons. • Other teachers responded that they use the Canva application to deliver teaching materials.
CK	• Teachers prepare materials from textbooks, teaching modules, and the internet. • Teachers feel confident when delivering materials because they have mastered the concepts and have teaching experience. • The material that teachers find difficult for students to understand is in the chapter on stoichiometry.
PK	• Most teachers use the Discovery Learning, Inquiry Learning, Problem-Based Learning, and Project-Based Learning models. • Each teacher has a strategy for managing the class.
PCK	• Each teacher develops initial strategies to get students interested in the chemistry material to be taught, such as by relating the material to everyday phenomena. • Teachers have strategies for delivering material that students find difficult, such as using simple analogies and explaining slowly and gradually.
TCK	• Teachers stated that the use of technology is quite effective in learning, especially for abstract material, because visual displays can make concepts clearer. • Teachers stated that they use technology to explain material, such as PowerPoint and YouTube videos. • The technology that teachers consider most effective in explaining material is PowerPoint.
TPK	• Technology-based learning strategies since the beginning of the semester. • Teachers adapt technology to the learning strategies or methods used. For example, when using the discussion method, teachers show videos of experiments via projectors as discussion material. • Teachers assess that technology reinforces pedagogical strategies and helps visualize material.
TPACK	• Teachers design learning by looking at teaching materials, appropriate methods and models, and determining the technology to be used. • Some teachers design TPACK-based learning from the beginning of the semester by adjusting to student characteristics and materials, determining the appropriate technology to support the delivery of these materials.

Observation Results

All findings from the observation process have been summarized and are shown in Figure 2.

Figure 2 Observation Recapitulation Results

The research began with the distribution of questionnaires to 48 high school/MA chemistry teachers in Bengkulu. The results of the questionnaire score recapitulation for 48 respondents are shown in Figure 1. The average achievement of all TPACK aspects was 85.96%, which is categorized as very good. This shows that, in general, high school/MA chemistry teachers in Bengkulu City have a good understanding of the TPACK concept and experience in integrating technology, pedagogy, and content into learning.

Implementation of the TPACK approach in high school/MA chemistry learning in Bengkulu City

a. Implementation of Technological Knowledge (TK)

The questionnaire results showed a 83.81% score in the "very good" category, indicating that teachers know and understand learning technology. The questionnaire findings were reinforced by interviews, with the results shown in Table 2.

The observation results showed that TK implementation only scored 49.52% in the "fair" category. The average score for each indicator is shown in Figure 3.

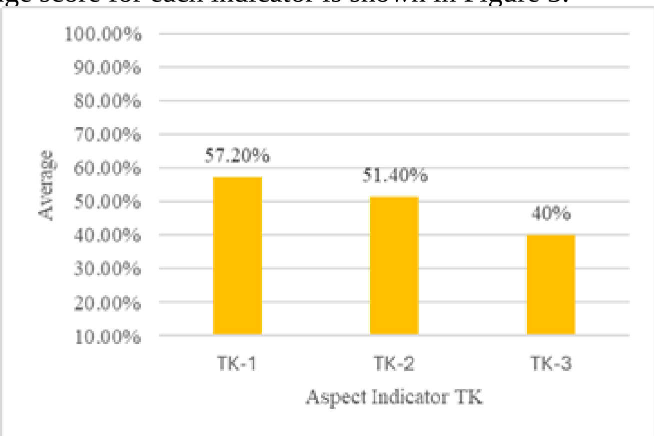

Figure 3 Average Indicator Diagram for the TK Aspect

The diagram shows that all indicators are in the "adequate" category. This is because only 4 of the 7 teachers used technology during the learning process, which affected the score. Observations also showed that only 2 of the 7 teachers used technology during learning evaluations, resulting in TK-3 receiving the lowest score. The differences in these observations reveal a gap between teachers' perceptions and classroom practices, where recognized technology is often used but not consistently or fully integrated into learning.

These findings are in line with the research by Irwanto et al. (2022), which states that Technological Knowledge (TK) tends to be weaker than pedagogy and content. Teachers are generally more confident in their mastery of subject matter and learning strategies than in their ability to use technology optimally in the classroom. This condition can be influenced by teachers' beliefs and perceptions of technology. Teachers who view technology as useful and easy to use tend to be more receptive to it and integrate it consistently into their teaching practices.

b. Implementation of Content Knowledge (CK)

The questionnaire results placed the score at 88.21% in the "very good" category. The interview results supported the questionnaire findings, which showed that teachers recognized stoichiometry as a topic students found difficult to understand. This is in line with the findings of Sari et al. (2024), who stated that students had difficulty understanding stoichiometry because of the many aspects that needed to be mastered, such as the concept of moles, balancing chemical equations, and the ability to convert verbal statements into mathematical form. This complexity requires students to spend more time fully understanding stoichiometry material. The observation results are in line with the questionnaire and interview findings, which scored 84.76% in the "very good" category. The average results for each indicator are shown in Figure 4.

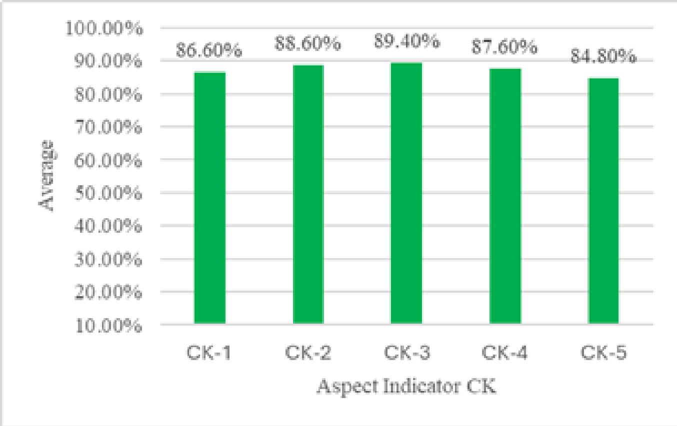

Figure 4 Average Diagram of CK Aspect Indicators

The diagram shows that all indicators are in the "very good" category, indicating that chemistry teachers have generally delivered the material systematically and in accordance with the concepts. Teachers also appear able to respond to student confusion during the learning process, so overall, the implementation of CK is very good and consistent across teachers' perceptions and its application in learning. This is in line with Chai et al. (2019) and Suradi (2025), who emphasize that Content Knowledge (CK) ensures the accuracy of material delivery, but does not automatically guarantee pedagogical skills in designing learning, managing class engagement, or accommodating the diversity of student needs.

c. Implementation of Pedagogical Knowledge (PK)

The questionnaire results show that the pedagogical knowledge aspect scored 87.60% in the "very good" category. The learning models that teachers have mastered are Discovery Learning, Inquiry Learning, Cooperative Learning, Problem-Based Learning, and Project-Based Learning. The questionnaire findings were reinforced by interviews, as shown in Table 2. The observation results supported the questionnaire and interview findings, with a score of 85.1% in the "very good" category. The average results for each indicator are shown in Figure 5.

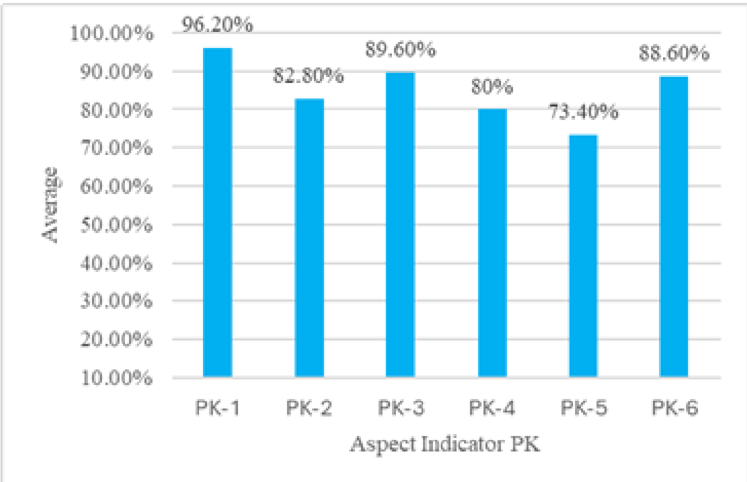

Figure 5 Average Diagram of PK Aspect Indicators

The diagram shows that indicators PK-4 and PK-5 are in the “good” category, while the others are in the “very good” category. Observations indicate that teachers generally manage their classes well, but some have not yet adapted their strategies to student characteristics, so differentiated strategies have not been implemented. This has been confirmed in the research by Rachmawati and Sutikno (2024), who found that TPACK-based differentiated learning improves learning outcomes because students learn according to their preferred learning styles, feel more comfortable, are more active, and are more courageous in expressing their opinions during discussions. Thus, improving teachers' ability to apply strategies that are adaptive to students' needs and varying abilities is an important aspect that needs strengthening in PK.

Overall, the implementation of PK has been very good, with teachers able to apply a variety of learning models and manage their classes, but the indicator of adjusting learning strategies to teaching materials still needs to be optimized.

d. Implementation of Pedagogical Content Knowledge (PCK)

The questionnaire results showed that in terms of pedagogical and content knowledge, the score was 89% in the “very good” category, indicating that teachers were able to choose effective learning approaches, relate the material to everyday phenomena, and evaluate learning outcomes in accordance with learning objectives. The questionnaire results were reinforced by interviews, as shown in Table 2. The observation results showed an average score of 84.76% in the “very good” category. The average score for each indicator is shown in Figure 6.

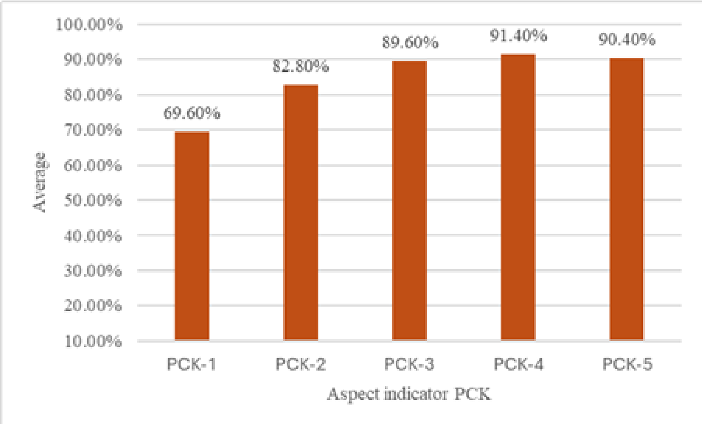

Figure 6 Average PCK Aspect Indicator Diagram

Based on the diagram above, only 1 indicator is in the “good” category: PCK-1. This is because based on the observations made, it was found that 3 out of 7 teachers did not convey the learning objectives to students, thus affecting the percentage. Research by Nurrahmawati et al. (2024) shows that clear learning objectives have a significant effect on science achievement, including students' critical thinking and problem-solving skills. Communicating learning objectives from the outset is an important part of PCK because it demonstrates the teacher's ability to link objectives, content, and learning strategies in a focused manner. Therefore, this aspect still needs to be strengthened in chemistry teaching practice.

Overall, the implementation of PCK aspects by chemistry teachers was excellent. This shows that teachers have been able to integrate pedagogical and content knowledge in delivering material, including linking chemistry concepts to everyday life and simplifying difficult material. However, it still needs to be strengthened in conveying learning objectives at the beginning of the activity to make the learning process more focused and optimal. However, it still needs to be strengthened in conveying learning objectives at the beginning of the activity to make the learning process more focused and optimal.

e. Implementation of Technological Content Knowledge (TCK)
The questionnaire results showed that the TCK aspect scored 84.69% in the “very good” category, indicating that teachers understand how to use technology to deliver learning materials. The interview results revealed distinct findings, summarized in Table 2.

Different findings were obtained during the observation, which showed an average score of 53.81% in the “fair” category. The average score for each indicator can be seen in Figure 7.

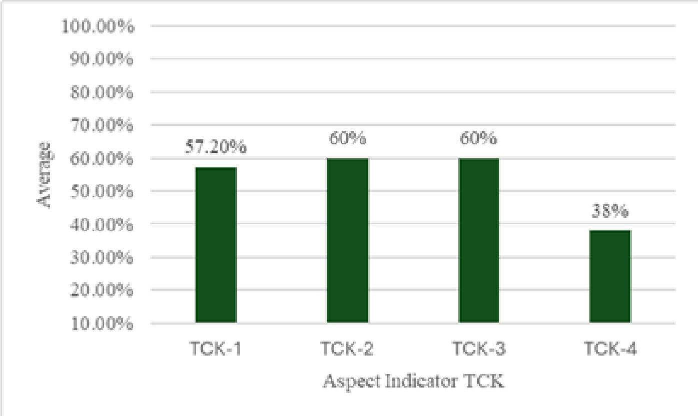

Figure 7 Average Diagram of TCK Aspect Indicators

The diagram shows that all indicators are in the “fair” category. This was because during the learning observation, only 4 of the 7 teachers used technology to deliver teaching materials, but during the evaluation activity, only 2 of the 7 teachers used it. Teachers tended to give assignments manually.

Overall, the implementation of the TCK aspect showed a gap between perception and practice. The questionnaire and interview results placed TCK in the “very good” category, because teachers felt that technologies such as PowerPoint and YouTube videos were effective for explaining abstract material. The observation results showed a “fair” category, because not all teachers utilized technology when teaching or during evaluation. This shows the need for greater consistency in the use of technology to optimize the implementation of TCK in learning practices.

f. Implementation of Technological Pedagogical Knowledge (TPK)
The questionnaire results showed that the TPK aspect scored 84.9% in the “very good” category, indicating that teachers understand how to use technology to support learning strategies. The results of the interviews are shown in Table 2. Different findings were obtained during the observation, which showed an average score of 64.76% in the “good” category. The average score for each indicator is shown in Figure 8.

The diagram shows that the indicators range from sufficient (TPK-2 and TPK-4) to good (TPK-1 and TPK-3). This is because during the learning observation, only 4 of the 7 teachers used technology to support learning strategies and conducted reflections. The TPK-4 results are in the good category, while the TPK-3 results are in the sufficient category. This is because during the learning observation, only 4 of the 7 teachers used technology to support learning strategies and conducted reflections. The TPK-4 results are in the good category, while the TPK-3 results are in the sufficient category. This is because during the learning observation, only 4 of the 7 teachers used technology to support learning strategies and conducted reflections. TPK-4) to good (TPK-1 and TPK-3). This is because during the learning observation, only 4 of 7 teachers used technology to support learning strategies and reflected on its use. Overall, the implementation of the Technological Pedagogical Knowledge (TPK) aspect was rated as good in the field. Although the questionnaire and interview results indicate that teachers' understanding is in the very good category, observations show that teachers have not consistently applied technology to support learning strategies. This indicates the need to strengthen implementation so that the integration of technology with pedagogical strategies can run more optimally.

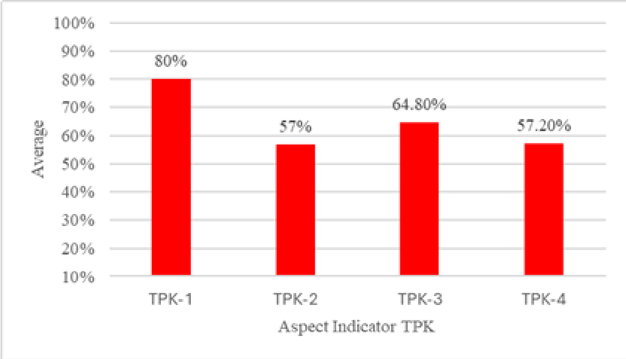

Figure 8 Average Diagram of TPK Aspect Indicators

g. Implementation of Technological Pedagogical and Content Knowledge (TPACK)
The questionnaire results showed that the TPACK aspect received a score of 83.5% in the "very good" category. This questionnaire finding was reinforced by the teacher interview results in Table 2. Different findings were observed, with an average score of 68.81% in the "good" category. The average achievement score for each indicator is shown in Figure 9. The questionnaire results show that the TPACK aspect obtained a score of 83.5% in the “very good” category. These questionnaire findings are reinforced by the teacher interview results shown in Table 2. Different findings were obtained during the observation, which showed an average score of 68.81% in the “good” category. The average score for each indicator is shown in Figure 9.

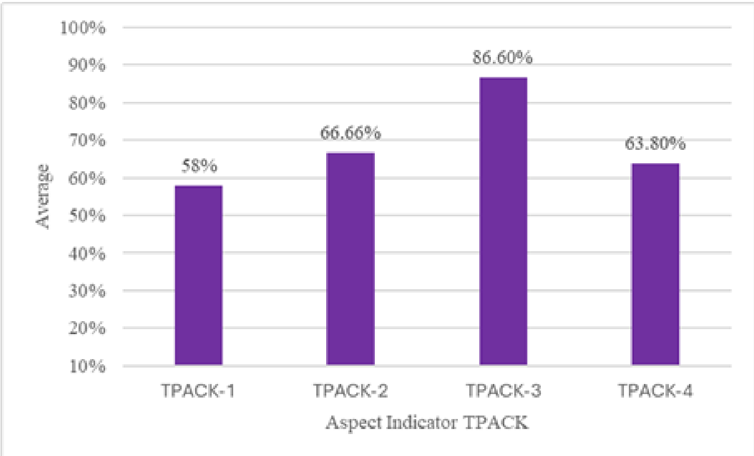

Figure 9 Average Diagram of TPACK Aspect Indicators

The diagram shows that only 1 indicator (TPACK-3) out of 4 indicators is in the “very good” category, 2 indicators are in the “good” category (TPACK-2 and 4), and 1 is in the “fair” category (TPACK-1). Observations revealed that some teachers use technological media to introduce concepts and encourage initial discussion, integrating chemistry content, learning methods, and technology to strengthen student understanding and respond to technical obstacles during the learning process.

These findings are in line with Ismail et al. (2023), who explain that even though teachers have designed TPACK-based learning before teaching, its implementation in the classroom is often constrained by technical factors such as limited internet access, computers, and LCDs. This condition reinforces the observation results in this study, which show that the integration of technology, pedagogy, and content is not yet fully optimal, even though teachers' understanding is in the very good category. In addition to operational barriers, secondary school teachers are also unprepared to use technology. This reinforces the observations in this study, which found that although teachers' understanding was excellent, the integration of technology, pedagogy, and content was not yet fully optimized.

Overall, the implementation of TPACK aspects showed a gap between understanding and classroom practice. This was demonstrated by the results of interviews and questionnaires, which categorized TPACK as very good. Interviews with teachers indicated that lesson plans were in place that integrated materials, strategies, and technology. However, in reality, the observations showed that the category was good, as not all indicators emerged optimally in learning practices. This indicates that TPACK implementation in the field is underway, but still needs to be strengthened to ensure a more consistent and comprehensive integration of technology, pedagogy, and content. These findings are in line with Tan et al. (2025), who stated that TPACK has a positive effect on teaching performance because teachers with high TPACK levels are better able to design and deliver learning that integrates technology, pedagogy, and content knowledge in a meaningful way.

Each aspect of TPACK has been analyzed separately, but a comparison of the overall implementation is needed. A recapitulation of the observation results for each aspect is presented in a bar chart in Figure 1. The diagram shows that the highest score was obtained by the CK (Content Knowledge) aspect, with 87.42% in the "very good" category, and the lowest by the TK (Technological Knowledge) aspect, with 49.52% in the "fair" category. The average achievement of all aspects was 71.1% in the "good" category. These results indicate that overall TPACK implementation is good, especially in the pedagogical and content aspects, but the use of technology in learning practices remains suboptimal. This condition indicates the existence of supporting and inhibiting factors that influence the implementation of TPACK.

Factors influencing the successful implementation of the TPACK approach

a. Supporting Factors

1. School Support

The results of interviews and observations show that school support plays an important role in the successful implementation of TPACK. Schools facilitate teachers through regular training, such as In-House Training (IHT), the dissemination of the Deep Learning approach, and technical support from the IT team and colleagues. Teachers who receive training and technical support appear better prepared to integrate technology into chemistry instruction.

This finding is reinforced by Nasrul et al. (2025), who state that most teachers experience difficulties in integrating technology due to limited pedagogical understanding of technology. Structured and practice-based training has been proven to minimize these obstacles, making regular training provided by schools an important factor in improving teachers' readiness to apply TPACK. In addition, school-level support, including technological infrastructure and teacher collaboration, also plays a role in increasing teachers' self-efficacy and positive attitudes towards the use of technology in learning (Cheng et al., 2025).

2. School Facilities

The availability of infrastructure, such as projectors and internet networks, also supports the implementation of TPACK, although it is not yet evenly distributed across all classrooms. Based on observations, the available facilities allow teachers to display PowerPoint presentations, videos, and other digital media during their teaching. This finding reinforces the idea that adequate technological facilities can enhance the effectiveness of technology integration in chemistry learning. With digital media, students can access study materials from anywhere, at any time (Handayani et al., 2021).

3. Teacher Motivation

Teachers who are highly motivated take the initiative to develop technology-based materials and modify them to fit their teaching methods. Teachers must be motivated and interested in adopting TPACK, even though not all of them use it in the classroom (Budiarti, 2024). Teachers who are highly motivated are more likely to develop innovative ways to incorporate technology into their lessons, whereas less motivated teachers are more likely to be hesitant to try new things. This demonstrates that the effective use of TPACK in the classroom depends heavily on motivation.

b. Hindering Factors

1. Student Device Readiness and Availability

The results of the interviews indicate that kids are still not prepared for digital literacy, and many do not have access to devices such as computers or cell phones. This restriction interferes with classroom activities and is consistent with the findings of Apriani et al. (2024), who reported that students lacking a steady internet connection or a technical device have trouble accessing the digital learning resources required for the TPACK approach. Technology-based learning is therefore unable to function at its best.

2. Limitations of School Devices and Internet Networks

Lack of hardware and poor internet connections pose serious stumbling blocks for teachers in implementing TPACK. Observations revealed that the absence of a permanent projector forces teachers to undertake laborious technical preparation, ultimately disrupting the efficiency of learning time. As a result, digital lesson plans are often canceled and replaced with whiteboards or printed worksheets due to technical difficulties. Moningka et al. (2025) also highlighted how poor connectivity hinders access to digital content, thus reducing the effectiveness of material delivery. In short, without hardware support (such as LCDs) and a reliable network, technology integration in education will remain a mere discourse, difficult to realize optimally.

3. Allocation of learning time

TPACK implementation is often hampered by limited learning time. Field observations indicate that teachers tend to prefer traditional methods because technology integration is perceived as requiring additional time for technical matters such as preparing media and devices. This situation aligns with Bingimlas's (2009) argument, which asserts that time for planning is a crucial constraint regardless of a teacher's proficiency with digital devices.

In conclusion, a deep understanding of TPACK does not always translate directly into classroom practice. Without adequate time allocated for preparation, technology integration will remain difficult to achieve optimal implementation in daily instructional activities.

CONCLUSION

Based on the research and discussion, it can be concluded that the level of understanding of the TPACK approach among high school chemistry teachers in Bengkulu City is generally in the very good category, as indicated by the questionnaire results (85.96%). Teachers demonstrated a good understanding of integrating technology, pedagogy, and content in lesson planning, but the observation results showed that TPACK implementation in the classroom was not yet fully consistent, particularly in the TK, TCK, and TPACK aspects, which remained in the fair-to-good range. This indicates a gap between teachers' perceptions of technology use and actual classroom practice. The main supporting factors in TPACK implementation include school support, facilities, and teacher motivation in developing technology-based learning. Meanwhile, the dominant inhibiting factors are limitations of student devices, the poor quality of the school's internet network, and limited learning time, which prevent teachers from fully integrating technology at every stage of learning.

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