



An Analysis of Planning, Implementation, and Evaluation of TPACK-Based Chemistry Instruction in Grade X at SMAN 5 Mataram

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Abstract

Technology integration in 21st-century learning is essential to enhance the quality of chemistry education, which is often perceived as abstract and complex. This study aims to analyze the planning, implementation, and evaluation of TPACK-based chemistry learning in Grade X at SMAN 5 Mataram. This research employed a descriptive qualitative approach using a case study design, with data collected through observation, interviews, and documentation. The results show that teachers have integrated technology across all stages of learning through PowerPoint, instructional videos, Google Classroom, and Quizizz. However, the use of technology remains predominantly as a tool for content delivery rather than as a means to facilitate higher-order thinking skills. It indicates that the implementation of TPACK has not yet reached a transformative level of learning. In conclusion, although TPACK has been implemented across the planning, implementation, and evaluation stages, its effectiveness in supporting instructional processes remains limited. This study underscores the need to strengthen teachers' competencies in designing technology-integrated learning that promotes critical and meaningful learning experiences. Practically, these findings can guide chemistry teachers in optimizing the use of digital tools to support more interactive and student-centered learning.

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INTRODUCTION

Chemistry instruction in secondary schools is complex and abstract, thus requiring a teaching approach that integrates macroscopic, submicroscopic, and symbolic representations (Wulandari & Sudarmin, 2019). Recent research emphasizes that failure to connect these three levels of representation is often the primary cause of low conceptual mastery and the emergence of misconceptions among students (Schwedler & Kaldewey, 2020; Permasari, 2024). In this context, the application of Technological Pedagogical Content Knowledge (TPACK) is crucial, as it enables teachers to integrate technology, pedagogy, and chemistry content simultaneously to enhance students' conceptual understanding (Mishra & Koehler, 2006; Nugroho & Suyanto, 2021). TPACK serves not only as a conceptual framework but also as an instructional strategy to help teachers design interactive, contextual learning

experiences oriented toward the development of higher-order thinking skills (Rahmadi, 2019; Chai et al., 2013).

In practice, integrating TPACK into chemistry instruction requires teachers to select and use relevant technologies, such as educational videos, animations, and digital platforms, to visualize abstract concepts that are difficult to grasp through conventional methods (Sari & Wahyuni, 2022; Hidayat, 2019). The use of TPACK-based interactive e-modules and virtual laboratories in the Merdeka Curriculum has been shown to significantly enhance the practicality and effectiveness of chemistry learning compared to static media (Edukatif, 2023; Santos & Castro, 2021). Concept visualization through Technological Content Knowledge (TCK) plays a crucial role in helping students more concretely understand the relationship between macroscopic and submicroscopic representations. Additionally, the appropriate use of technology can enhance student engagement and foster more meaningful learning (Voogt et al., 2013).

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However, various studies indicate that implementing TPACK in schools still faces significant challenges (Putri & Nugroho, 2021). Although many teachers have high quantitative scores in technology knowledge, actual classroom implementation is often still "superficial" and has not yet addressed deeper pedagogical aspects (Sidoarjo Study, 2024; Wulan et al., 2026). Teachers' mastery of TPACK tends to remain at a conceptual level and has not been fully implemented in teaching practices that foster active student engagement (Rahmadi, 2019). Furthermore, the use of technology in learning remains predominantly limited to serving as a tool for delivering content, rather than being optimally used to develop higher-order thinking skills (Kurniawan & Andriani, 2020). Recent research in Indonesia has identified the main constraint as the lack of synchronization between digital planning and the assessment of authentic learning outcomes (Raskha Media, 2026).

This situation is also reflected in the results of preliminary observations conducted at SMAN 5 Mataram. The school already has digital learning support resources, such as Google Classroom, PowerPoint presentations, and instructional videos, which are routinely used in the chemistry curriculum. However, based on initial observations, the use of these technologies still tends to focus on content delivery, while students' active engagement in developing a deep conceptual understanding remains suboptimal. These characteristics make SMAN 5 Mataram a relevant context for examining the implementation of TPACK, particularly in assessing the alignment between planning, implementation, and evaluation of technology-based learning.

These findings indicate that previous studies have tended to focus on either teacher competencies or the use of technology in isolation, and have not comprehensively examined the integration of planning, implementation, and evaluation of TPACK-based learning in the context of school chemistry instruction. Consequently, a research gap remains regarding how TPACK is implemented holistically across all stages of the learning process. Based on this gap, this study aims to analyze the planning, implementation, and evaluation of TPACK-based chemistry learning in 10th-grade classes at SMAN 5 Mataram. This study offers a novel approach by comprehensively examining the implementation of TPACK across all stages of learning in a real-world classroom context, thereby providing empirical contributions to the development of more effective chemistry instruction and serving as a reference for teachers in optimizing the use of technology.

MATERIALS AND METHODS

Time and place

This study was conducted over a three-month period, from March to May 2025, at SMAN 5 Mataram in West Nusa Tenggara. The research site was selected for its implementation of technology-based chemistry instruction relevant to the study's focus, particularly in the 10th-grade class. The research was conducted in several stages with a structured timeline. The observation phase consisted of four sessions aligned with the chemistry curriculum schedule for Class X-10. Two interviews were conducted with the chemistry teacher to gather data regarding TPACK-based lesson planning and assessment. Meanwhile, documentation was conducted throughout the research

process, including the collection of instructional materials, such as teaching modules, worksheets, and learning media.

Overall, the preparatory phase will take place in early March 2025, the data collection phase (observations, interviews, and documentation) will be conducted from mid-March through late April 2025, and the data analysis and preparation of the research report will take place in May 2025.

Research design

This study employs a qualitative approach using a descriptive case study design. The qualitative approach was used to gain an in-depth understanding of learning phenomena under real-world field conditions, particularly the planning, implementation, and evaluation of TPACK-based learning. A case study was chosen because this research focuses on a single class as the unit of analysis, thereby allowing the researcher to examine in depth the implementation of TPACK in the context of chemistry learning in the 10th-grade class at SMAN 5 Mataram (Yin, 2018).

The strength of qualitative research in science education lies in its ability to uncover the meaning behind the interactions between teachers and students with technological tools in a naturalistic manner (Hadi & Nurkholis, 2019; Suardi, 2020). Descriptive research aims to systematically and factually describe the characteristics of the objects under study (Sugiyono, 2019; Moleong, 2017). Therefore, this study is observational, in which the researcher does not provide any treatment or intervention in the learning process but rather observes and analyzes the implementation of TPACK that occurs naturally in the classroom.

Research Population and Sample

The population in this study consisted of all chemistry instruction activities in 10th-grade classes at SMAN 5 Mataram, which comprises 12 parallel classes. The research sample was selected using purposive sampling, a method in which subjects are chosen based on specific criteria relevant to the research objectives (Sugiyono, 2019; Patton, 2015). The sample selected was Class X-10, consisting of 36 students. This class was chosen because it demonstrated a higher level of learning technology use than other classes. Based on the results of the initial observation, Google Classroom was used routinely at every meeting in Class X-10 for the distribution of materials and the collection of assignments, whereas in other classes, its use remained limited to certain meetings. In addition, teachers consistently used PowerPoint and educational videos in every learning session and utilized digital assessment platforms such as Quizizz for formative assessment activities.

The selection of Class X-10 was based on the consideration that this class demonstrated teaching practices that actively integrated technology into the planning, implementation, and evaluation of learning. This made it an information-rich case, allowing researchers to obtain in-depth data on the mechanisms of TPACK integration. Purposive sampling of groups with high levels of digital literacy is highly recommended in recent qualitative research to explore the complexities of technology integration not found in conventional classrooms (Creswell & Poth, 2024; Patton, 2024). Furthermore, focusing on a single representative class

enables a more nuanced analysis of interactions among teachers, students, and digital media within a specific context (Putra & Saputra, 2026).

This study focuses on three main aspects: the planning, implementation, and evaluation of TPACK-based chemistry instruction. These three aspects are analyzed through the interrelationships among the TPACK components: Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Pedagogical Content Knowledge (PCK). Re-examining these components is highly relevant in modern chemistry instruction to ensure that the use of digital tools does not obscure the subject matter's abstract nature (Koehler, Mishra, & Cain, 2013; Rosenberg & Koehler, 2020). The analysis examines the intersection of these three components to provide a comprehensive understanding of TPACK implementation in chemistry instruction.

Data were collected through observation, interviews, and documentation. This multidimensional approach was necessary to validate the depth of technology integration by teachers, given the increasingly complex challenges of digital transition in the current curriculum (Wulan et al., 2026; Santos & Castro, 2021). The instruments used include TPACK-indicator-based observation sheets, semi-structured interview guidelines, and documentation in the form of learning resources such as teaching modules, worksheets, and learning media used by teachers. The measurements conducted at all these stages aim to identify whether technology integration has reached a transformative level, rather than merely substituting conventional media (Nurani et al., 2026; Rahmadi, 2019; Sudarsono & Kurniawan, 2021).

Research procedure

This research procedure was carried out in several stages, namely: (1) the preparation stage, which included the development of research instruments and a preliminary study; (2) the implementation stage, which involved conducting direct observations of the learning process, interviewing teachers, and collecting documentation; (3) the data processing stage, which involves organizing and classifying the data obtained; and (4) the analysis and conclusion-drawing stage. This procedure follows the stages of qualitative research, which include data collection, data reduction, data presentation, and drawing conclusions (Miles et al., 2014). This cyclical procedure ensures that all collected data is closely aligned with the focus on technology integration in the classroom (Rahman, 2021).

Research data analysis

Data analysis in this study was conducted using an interactive qualitative data analysis model comprising three main stages: data reduction, data presentation, and drawing conclusions. This model allows researchers to conduct analysis continuously from the beginning of data collection through to the end of the research process (Miles, Huberman, & Saldaña, 2020). Data reduction was carried out by selecting, focusing on, and grouping relevant information from observations, interviews, and documentation. Subsequently, the data were presented as descriptive narratives to facilitate the researchers' identification of emerging patterns, relationships, and trends. The final stage involved drawing conclusions,

which was conducted iteratively and continuously verified throughout the research process.

To ensure the validity of the data, source triangulation and methodological triangulation were employed. Source triangulation was conducted by comparing data from various contexts, including classroom observations, teacher interviews, and instructional materials (teaching modules, PowerPoint presentations, and worksheets). Meanwhile, methodological triangulation was achieved by combining multiple data collection methods. The application of these various data collection techniques is crucial in TPACK research to minimize subjectivity and ensure that the data obtained comprehensively complement one another (Denzin & Lincoln, 2023; Rahmadi, 2019).

In the analysis, the researcher focused on identifying and examining the relationships among the TPACK components: TCK, TPK, and PCK. The TCK analysis category involved selecting and using digital media to represent abstract chemical concepts. The TPK analysis category covers learning strategies that use technology to support student interaction, while the PCK category is analyzed by examining the alignment between pedagogical strategies and the characteristics of chemistry content. This analytical approach, which focuses on the intersection of these components, allows researchers to map the dynamics of "TPACK-in-Action," which are often situational and complex (Nurani et al., 2026; Wulan et al., 2026).

RESULTS AND DISCUSSION

Result

TPACK-Based Chemistry Instructional Planning

The research findings indicate that teachers have implemented lesson planning based on Learning Outcomes (CP) and Learning Objectives in accordance with the Merdeka Curriculum. Based on the documentation, the instructional materials developed include teaching modules, instructional materials, learning media, and assessment instruments. Observation results indicate that prior to the lesson, teachers prepared digital media such as PowerPoint presentations and instructional videos. Additionally, teachers designed technology-supported, group-discussion-based learning activities. The interview results indicate that the choice of media was driven by the need to visualize abstract chemical concepts so students could understand them more easily. Details of the instructional materials are presented in Table 1.

Table 1. Analysis of TPACK-Based Instructional Materials

Instructional Components	Availability	Description of Technology Integration
Teaching Module / Lesson Plan	Available	Includes structured steps for the use of digital platforms
Learning Media	Available	Utilizes PowerPoint presentations and instructional videos
Student Worksheets (LKPD)	Available	Provided in digital format via Google Classroom
Assessment Instruments	Available	Employs interactive quiz applications (e.g., Quizizz)

Based on the documentation and observations, the integration of technology into lesson planning is also evident in the appropriate use of different media types to match the characteristics of the chemical material. In lessons on atomic structure and chemical bonding, videos are used to visualize microscopic particles, while PowerPoint is used to present symbolic representations.

Implementation of TPACK-Based Chemistry Instruction

The observation results show that the lesson consists of an opening, a main body, and a closing. During the opening, the teacher provides motivation, an introduction, and ice-breaking activities. During the main body, the lesson is conducted through group discussions and problem-solving. The teacher uses PowerPoint and educational videos, while students access learning materials via barcodes and complete digital worksheets through Google Classroom. The interview results indicate that the use of technology is intended to facilitate the delivery of material and increase student engagement. The learning activities are summarized in Table 2.

Table 2. Analysis of Learning Stages and Teacher-Student Activities

PBL Stages	Teacher and Student Activities	TPACK Integration
Problem Orientation	Students observe phenomena through instructional videos	TCK – Videos are used to visualize abstract chemistry concepts
Organizing Learning	The teacher distributes digital worksheets via Google Classroom	TPK – Digital platforms are utilized to manage learning activities
Investigation	Students search for information through barcode-based learning materials	TCK & TPK – Technology is used to facilitate conceptual exploration
	Student complete quizzes via Quizizz and engage in reflection	TPK – Technology supports assessment and feedback processes

During the closing activity, the teacher and students summarized what they had learned and conducted a brief review of the material covered.

Evaluation of TPACK-Based Chemistry Instruction

The research findings indicate that assessments were conducted in both formative and summative formats. Based on observations, formative assessments were conducted using Quizizz, which provided students with immediate feedback. Interview results indicate that assessment results were used to identify students' understanding and to provide feedback. In addition to cognitive aspects, the observations indicate that teachers also assess affective and psychomotor aspects during group discussions. Affective aspects include student engagement, cooperation, and participation, while psychomotor aspects include the ability to use digital media. However, these assessments have not yet utilized structured instruments. The documentation shows that the evaluation results are used as a basis for reflection to improve learning.

Discussion

Analysis of Instructional Planning from a TPACK Perspective

The instructional planning carried out by teachers demonstrates the integration of technological, pedagogical, and content components. This aligns with the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes that the effectiveness of digital learning depends on the dynamic synergy between subject matter knowledge, teaching methods, and the tools used. In the current era of digital transformation, thorough planning in these areas is no longer merely an option but a prerequisite for creating an adaptive learning environment (Amador et al., 2021; UNESCO, 2023). In the context of education in Indonesia, the ability to design TPACK-based learning has become a vital indicator of teachers' professional competence in addressing the dynamics of the Merdeka Curriculum, which demands flexibility in instructional tools (Syahputra & Hafiz, 2024).

The use of media such as PowerPoint and educational videos indicates that teachers have incorporated Technological Content Knowledge (TCK), particularly in visualizing abstract chemical concepts. Sub-microscopic visualization through digital media has been shown to bridge students' cognitive gaps in understanding molecular structures and reaction mechanisms that are not visible to the naked eye (Akaygun & Karatas, 2020; Permasari, 2024). This aligns with findings that dual representations (macroscopic and submicroscopic) designed within digital modules significantly reduce misconceptions in basic chemistry material (Fikri et al., 2025).

However, further analysis indicates that instructional planning still tends to focus on lower-order thinking skills and has not yet been explicitly designed to develop higher-order thinking skills (HOTS). This is evident in the absence of complex problem-solving or inquiry-based activities integrated with technology. This finding indicates that the integration of TPACK at the planning stage remains at a technical-substitutive level, rather than a pedagogical-transformational one.

This situation reinforces the argument that many educators remain trapped in using technology merely to enhance content presentation, without shifting the instructional paradigm toward a more collaborative approach (Chun & Heo, 2022; Nurani et al., 2026). In Indonesia, this limitation is often triggered by a planning focus that prioritizes administrative compliance over the design of innovative activities that foster independent knowledge construction (Pratama & Prasetyo, 2025). Thus, the novelty of this study lies in identifying that the stagnation of TPACK quality in class X-10 stems from a planning stage that has not fully explored the pedagogical potential of technology.

Analysis of Instructional Implementation from a TPACK Perspective

The instructional implementation demonstrated that teachers had integrated technology through PowerPoint, instructional videos, Google Classroom, and digital worksheets. This integration reflects the application of Technological Pedagogical Knowledge (TPK), in which technology is used to support instructional strategies such as group discussions and problem-based learning. The use

of digital platforms during the collaboration phase has been shown to enhance information retention and facilitate a more equitable distribution of roles within groups (Hamilton et al., 2023; Wijaya et al., 2025). The use of such technology has been shown to increase student engagement, particularly during the problem-orientation and group discussion stages. Additionally, implementing group discussions demonstrates a student-centered learning approach that contributes to improved conceptual understanding (Setiawan, 2020).

However, a more in-depth analysis reveals that the use of technology has not yet reached the level of learning transformation. When analyzed using the SAMR model, the use of technology in this context remains at the substitution and augmentation levels. This aligns with the phenomenon of “old pedagogy in a new bottle,” in which digital devices are used merely to replicate traditional lecture methods without redefining learning tasks (Terada, 2020; Raskha Media, 2026). There is no evidence yet of activities leading to the modification or redefinition levels, such as simulation-based independent exploration or virtual experiments. Students still act as recipients of information, not yet as active knowledge constructors. This situation indicates that TPACK integration remains procedural, not yet reaching the epistemic level that drives transformation in how students learn (Kimmons et al., 2020).

Analysis of Learning Assessment from a TPACK Perspective

The learning evaluation indicates the integration of technology through the use of the Quizizz app as a formative assessment tool. The use of Quizizz facilitates rapid feedback and enhances student engagement. Gamification in formative assessment, through Quizizz or similar platforms, can reduce test anxiety and provide teachers with instant diagnostic data to implement interventions (Zainuddin et al., 2020; Pratama, 2025). However, the use of Quizizz in this study remains at the substitution level, as it merely replaces conventional tests with a digital format without altering the assessment’s characteristics. The questions administered are still predominantly multiple-choice, measuring cognitive aspects and thus not yet reflecting HOTS-based evaluation.

Furthermore, assessments of affective and psychomotor aspects are still conducted conventionally without the support of structured digital tools. This indicates that the integration of TPACK into assessment has not yet comprehensively covered all learning domains. To achieve higher levels of assessment (modification and redefinition), teachers need to develop more complex digital assessment tools. The transformation of digital assessment must lead to an authentic assessment that captures traces of collaboration and problem-solving skills in real time (Munawaroh, 2020). Therefore, the development of TPACK-based assessment should be directed not only toward the digitization of instruments but also toward a paradigm shift in assessment toward a holistic approach that encompasses 21st-century skills.

CONCLUSION

Based on the research findings, the implementation of Technological Pedagogical Content Knowledge (TPACK) in chemistry instruction for 10th-grade students at SMAN 5 Mataram has been carried out across three main aspects: planning, implementation, and

evaluation. During the planning phase, teachers integrated technological, pedagogical, and content components by developing systematic digital instructional materials. During the implementation phase, instructors used various digital media and platforms, such as PowerPoint, instructional videos, and Google Classroom, to support student learning activities. Meanwhile, during the evaluation phase, technology-based applications such as Quizizz were utilized for formative assessment. However, the use of technology in learning still tends to be limited to serving as a medium for conveying information and has not yet fully supported the optimal development of students’ Higher Order Thinking Skills (HOTS).

The implications of this study highlight the importance of enhancing teachers’ competencies in integrating technology more adaptively and innovatively, not merely as a learning aid but as a means of fostering students’ cognitive transformation. In practical terms, teachers are advised to: (1) design problem-based learning activities integrated with digital technology, such as the use of interactive simulations or virtual experiments to encourage the exploration of chemical concepts; (2) develop Higher-Order Thinking Skills (HOTS)-based assessment instruments through digital platforms, such as project-based assessments, digital portfolios, or rubrics integrated into a Learning Management System; and (3) utilize technology to support collaborative and reflective learning, for example through online discussions or digital presentations. This study has limitations in its scope, as it involved only one class, and thus cannot yet describe the implementation of TPACK more broadly. Therefore, future research is recommended to involve a more diverse sample and to examine in greater depth the impact of TPACK implementation on higher-order thinking skills.

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AUTHOR'S CONTRIBUTION

All authors contributed to the preparation of this article in accordance with their respective roles. The first author played a leading role in all stages of the research, from conceptualization and research design to field data collection, data analysis, and the preparation of the initial draft. The second and third authors contributed to the validation of the methodology, literature review, and the manuscript review and editing process. The fourth author contributed to strengthening the literature review, developing supporting instruments, and assisting in the final editing of the manuscript. All authors approved the final version of the published article.

Table of Author Contributions

Contribution Indicators	Author				
	1	2	3	4	5
Conceptualization	✓	✓		✓	
Literature Review	✓		✓	✓	✓
Research Design / Methodology	✓	✓	✓		
Instrument Development	✓	✓			✓
Data Collection	✓				
Data Curation	✓	✓			
Formal Analysis		✓	✓		
Data Interpretation	✓		✓	✓	
Writing – Original Draft	✓				
Writing – Review & Editing	✓	✓	✓	✓	✓
Visualization / Tables	✓				✓
Supervision	✓	✓	✓	✓	✓

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