

CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHING LEWIS STRUCTURE

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Abstract

Lewis structures remain a challenge in chemistry teaching. Many studies have examined students' misconceptions about Lewis structures, but studies specifically analyzing how teachers' Pedagogical Content Knowledge (PCK) influences teaching practices on this topic are still limited. This study aims to analyze chemistry teachers' PCK on the topic of Lewis Structures by examining its three components, Content Knowledge (CK), Student of Knowledge (KS), and Pedagogical Knowledge (PK), and see the relationship between the three. This study uses a qualitative descriptive approach, involving 5 chemistry teachers in the Cilegon area. Data were collected through conceptual understanding test, semi-structured interviews, and an analysis of teachers' lesson plan documents. Data validity was ensured through triangulation of sources and data collection techniques. Data were analyzed through data reduction, data display, and conclusion drawing. The results of the study showed that although 80% of teachers were able to distinguish Lewis symbols and Lewis structures, 40% of teachers had misconceptions about the octet rule, only 20% were able to calculate formal charges correctly, and all teachers had difficulty achieving resonance with atomic charge distribution. This limitation of Content Knowledge (CK) has an impact on the low ability of teachers to identify student misconceptions (KS) as well as on learning strategies that tend to be procedural and lecture-centered (PK). These findings indicate that the interaction between CK, KS, and PK determines the quality of teachers' PCK and emphasizes the importance of strengthening conceptual CK in the professional development of chemistry teachers.

Key words: content knowledge, knowledge of students, pedagogical knowledge, PCK, lewis structure

INTRODUCTION

Chemistry is a subject that requires deep conceptual understanding and the ability to relate phenomena at various levels, from the macroscopic, microscopic, to the symbolic[1]. The interrelation between these three levels of representation requires students to accurately interpret and use various forms of chemical representation. These representations, including symbols, formulas, diagrams, graphs, and both two- and three-dimensional models, play a critical role in helping students develop a comprehensive understanding of chemical phenomena[2].

One concept that relies heavily on representational skills is Lewis structures, as they require the ability to describe and interpret the relationships between atoms in a molecule. Lewis structures are introduced early in chemistry education because they provide sufficient information to predict the properties of

substances[3]. Understanding this concept allows students to relate molecular structure to its macroscopic behavior, such as molecular geometry, chemical properties, and reactivity[4]. Therefore, a thorough understanding of Lewis structures provides an important foundation for developing meaningful conceptual knowledge in chemistry and facilitates the understanding of more complex chemical concepts[5].

Chemistry learning is not only determined by students' understanding of the subject matter, but also by the teacher's ability to integrate chemical content knowledge with appropriate pedagogical strategies[6]. Teachers who have strong content and pedagogical knowledge can effectively connect chemistry concepts to students' learning experiences[7] and choose learning strategies that can facilitate students' understanding of abstract chemical concepts[8]. Thus, content and pedagogical knowledge reflect the integration of

understanding of subject matter and teaching strategies used by teachers to make learning more effective and appropriate to students' learning needs. [9].

Understanding integration of the content knowledge and pedagogical knowledge forms the basis of the concept of Pedagogical Content Knowledge (PCK), which represents teachers' professional knowledge emphasizing the relationship between what is taught and how it is taught[10]. PCK is the link between content knowledge and pedagogical knowledge. Many researchers have developed models of PCK, one of which is the model developed by Gess-Newsome (1999), which views PCK as a dynamic interaction between content knowledge (CK), pedagogical knowledge (PK), and student knowledge (KS), where each component remains distinct but interrelated. In this model, each component of PCK has a specific role. Content Knowledge (CK) represents the teacher's understanding of the subject matter, including core concepts, theories, and disciplinary structures[11]. Pedagogical Knowledge (PK) refers to teachers' understanding of teaching strategies, classroom management, and methods to facilitate learning, while Knowledge of Student (KS) encompasses teachers' awareness of students' prior knowledge, learning difficulties, and contextual factors that influence learning. This model provides a comprehensive conceptual framework for understanding how teachers integrate different types of knowledge into their teaching practices.[12].

Research reveals that the implementation of the three PCK components has not been fully reflected in classroom teaching practices[13]. Many chemistry teachers still face challenges in connecting scientific concepts to students' thinking, especially on abstract topics[7], [9], [13], [14]. This suggests that teachers have not fully utilized the integration of CK, PK, and KS in teaching conceptual representations such as Lewis structures. Research specifically examining how teachers' PCK influences the teaching of Lewis Structures is still very limited. Most existing studies focus on students' misconceptions, thus providing insufficient insight into how teachers utilize their knowledge of students and their

pedagogical strategies when teaching Lewis Structures. Therefore, this study is needed to address this gap by investigating how teachers' PCK specifically influences their teaching strategies in teaching Lewis Structures and by revealing how teachers transform conceptual knowledge into meaningful learning experiences for students. This analysis is expected to provide a comprehensive understanding of how teachers' CK, PK and KS in teaching of Lewis Structures.

METHOD

This study uses a descriptive qualitative approach to provide an in-depth understanding of chemistry teachers' Pedagogical Content Knowledge (PCK) in teaching Lewis structures. This approach was chosen because it allows researchers to explore in depth how teachers integrate content knowledge, pedagogical knowledge, and knowledge about students in the learning process. The subjects consisted of five chemistry teachers from five different high schools in the Cilegon Banten, each teacher having a minimum of five years of teaching experience. The subjects were selected by purposive sampling based on accessibility to ensure that interviews and data collection could be carried out effectively.

The research instruments consisted of a conceptual understanding test, semi-structured interviews, and an analysis of teacher lesson plan documents. The test instruments were developed based on misconceptions related to Lewis structures identified in various previous studies. These misconceptions then used as the basis for developing indicators and test items aimed at exploring teachers' conceptual understanding. The test was used to assess teachers' content knowledge (CK). Content validation was conducted through expert judgment by two chemistry education lecturers.

Pedagogical knowledge (PK) and student knowledge (KS) were explored through semi-structured interviews. The interview guide was developed with reference to the three components of PCK, so the questions addressed teachers' understanding of the concept of Lewis structures (CK), the strategies they use to teach it (PK), and their predictions regarding student misconceptions

(KS). Sample interview questions included: "How do you introduce and teach the steps of drawing Lewis structures?" and "How do you identify students' misconceptions regarding the octet rule?".

Lesson plan documents analysis was conducted to examine the extent to which the three components of PCK were reflected in the teaching process. Data validity was ensured through triangulation of data collection sources and techniques. Triangulation was conducted by comparing data from various methods, including conceptual understanding tests, interviews, and learning documents such as lesson plans, teaching materials, and teacher worksheets. Findings from the tests were then confirmed through interviews and cross-checked with the learning strategies contained in the learning documents. To enhance validity, member checking was used by asking teachers to confirm the researcher's interpretation of the data. This approach ensured the credibility of the findings and provided a deeper understanding of teachers' learning practices. The data analysis process involved data reduction, data presentation, and drawing and verifying conclusions[15].

RESULTS AND DISCUSSION

The results of the study are intended to explain the patterns and depth of teachers' pedagogical content knowledge in teaching Lewis structure, not to be generalized widely due to the limited representativeness of participants. The results show that all teachers exhibit similar patterns in the three components of Pedagogical Content Knowledge (PCK): Content Knowledge (CK), Pedagogical Knowledge (PK), and Knowledge of Student (KS). However, slight variations in CK were observed for each Lewis structure subconcept. These variations in CK also shaped teachers' KS and PK, as elaborated in the following section.

Content Knowledge (CK)

Teachers' Content Knowledge (CK) reflects an adequate understanding of fundamental concepts. However, it remains limited in representing Lewis structures of complex molecules or non-octet molecules. Furthermore, their understanding of molecular stability is limited, several teachers were unable to associate molecular stability with the concept of formal charge. A general overview of teachers' content understanding is presented in the Table 1.

Table 1. Teachers' Content Knowledge

No.	Subconcept	Content Knowledge	Finding
1.	Lewis Symbols	80% of the teachers understood the difference between Lewis symbols and Lewis structures, while one teacher considered them the same.	Most teachers showed good content knowledge (CK).
2.	Octet Rule	40% of the teachers believed that all atoms "must" have an octet to be stable. The other 60 % recognized exceptions to the octet rule but did not understand the reasons behind the stability of molecules that violate the rule.	CK is still procedural; teachers are unable to explain exceptions or the stability of non-octet molecules.
3.	Lewis Structures	All teachers could draw simple Lewis structures but struggled with molecules that deviate from the octet rule.	CK is limited, focused on procedures, and does not fully consider molecular stability.
4.	Formal Charge	20% of the teachers correctly calculate the formal charge.	Low CK; several teachers lack a clear conceptual understanding of formal charge.
5.	Resonance	All teachers stated that resonance increases molecular stability.	Good CK, but lacks an in-depth explanation of how resonance relates to the distribution of atomic charges.

Based on Table 1, most teachers correctly understood the concepts of valence shells and

valence electrons, although misconceptions persisted in symbolic representation. Three teachers

correctly understood the octet rule, whereas two others believed that atoms that do not octet are always unstable. This finding indicates that teachers' understanding remains partial and incomplete likely because they had not yet connected the stability of non-octet molecules to the formal charge concept. Contextual factors, such as curriculum emphasis on standard molecules and limited instructional time for complex structures, may have further contributed to these gaps[16].

Teachers were generally able to represent Lewis structures for simple molecules, but encountered difficulties when dealing with molecules that deviate from the octet rule, their understanding tended to be procedural rather than conceptual[17]. Only one teacher was able to calculate formal charge correctly, but was unable to relate it to molecular stability. Furthermore, although all teachers recognized the role of resonance in maintaining molecular stability, their explanations were limited to electron transfer without considering the distribution of charge between atoms. These limitations indicate that teachers' content knowledge is influenced by prior knowledge, thus affecting their ability to conceptually interpret abstract chemical concepts.

These findings indicate that limited Content Knowledge (CK) hinders teachers' ability to

integrate chemistry concepts into the learning process. Limited understanding makes it difficult for teachers to explain the relationships between subconcepts, such as formal charge, resonance, and molecular stability. This condition is in line with the finding that Knowledge is the foundation for the formation of Pedagogical Content Knowledge (PCK), where a strong conceptual understanding is crucial for teachers to transform material into meaningful learning for students.[7].

Knowledge of Students (KS)

Teachers' limited Content Knowledge (CK) also impacts their understanding of students' knowledge (KS)[8]. Teachers who focus on the octet rule and the procedural aspects of drawing Lewis structures are often less able to recognize students' difficulties or misconceptions, especially concerning formal charge and molecular stability. In this way, gaps in CK can restrict teachers' ability to identify students' learning needs and address their misconceptions effectively. Table 2 presents the interpretation of chemistry teachers' Knowledge of Students (KS) for each sub-concept of Lewis structures.

Table 2. Teachers' Knowledge of Students

No.	Subconcept	Content Knowledge	Finding
1.	Lewis Symbols	All teachers were unaware that students could be confused between Lewis symbols and Lewis structures.	KS is limited; potential student misconceptions remain.
2.	Octet Rule	Some teachers did not notice students' difficulties with non-octet molecules.	KS is limited; misconceptions may persist.
3.	Lewis Structures	Teachers recognized students struggle with complex or non-octet molecules.	KS is moderate; awareness exists but errors are not fully minimized.
4.	Formal Charge	Teachers were unaware of students' difficulties with formal charge.	KS is low; misconceptions are not visible.
5.	Resonance	Teachers did not realize students' partial understanding of resonance and atomic charge distribution.	KS is limited; misconceptions persist.

Overall, these findings indicate that teachers' knowledge of students' difficulties and thinking processes regarding Lewis structures is still not optimal. In the Lewis symbol subconcept, all teachers were unaware that students might confuse Lewis symbols with Lewis structures.

Although most teachers possessed adequate Content Knowledge (CK) in this subconcept, they had not anticipated the potential misconceptions that might arise. This limitation seems to be influenced by the fact that the Lewis symbol subconcept is rarely emphasized in classroom

instruction, and teachers rely largely on personal assumptions rather than systematic observation of student thinking.

In the octet rule subconcept, teachers were unaware of the potential difficulties students might encounter due to their own limited understanding of the underlying reasons for the stability of atoms that do not follow the octet rule. Teachers' lack of in-depth understanding of the concept (CK) related to the octet rule allows students to experience similar difficulties because teachers cannot guide students to construct the correct concept. Limited teaching time and textbook coverage can exacerbate this situation. The same thing was also found for the resonance subconcept. teachers' limited conceptual understanding of electron delocalization limits their ability to predict students' misconceptions, indicating that CK and KS are closely related.

In the Lewis structure subconcept, teachers recognized that many students had difficulty drawing molecular structures. This awareness emerged because the teachers themselves experienced similar challenges when asked to write Lewis structures, particularly for compounds that do not follow the octet rule, such as NO_2 and SO_3 . Meanwhile, in the formal charge subconcept, student misconceptions or difficulties were not identified because most teachers also did not understand the concept. Teachers considered formal charge to be an unimportant topic to teach,

especially because it was not included in the textbooks they used. This limited Content Knowledge contributed to low Knowledge of Students (KS), causing teachers to be unaware of students' potential difficulties in understanding electron distribution and structural stability.

Overall, chemistry teachers' Knowledge of Students (KS) regarding Lewis structures remains limited. Teachers tend to be unable to identify students' difficulties and misconceptions in depth due to constraints in their own Content Knowledge (CK). Their understanding of students' thinking is strongly influenced by personal experience and assumptions, rather than systematic analysis of student learning, highlighting the interaction between teachers' CK, classroom context, and KS. Teachers who lack an understanding of students' thinking tend to overlook emerging misconceptions[18].

Pedagogical Knowledge (PK)

Teacher awareness of student misconceptions is a crucial component in designing effective instructional strategies[19]. Therefore, teachers' limited understanding of students directly affects their Pedagogical Knowledge (PK), including teaching strategies, classroom management, and efforts to facilitate learning on Lewis structure topics. Table 3 presents an interpretation of chemistry teachers' Pedagogical Knowledge (PK) for each Lewis structure subconcept.

Table 3. Teachers' Pedagogical Knowledge

No.	Subconcept	Pedagogical Knowledge	Finding
1.	Lewis Symbols	All teachers did not explain Lewis symbols and directly discussed Lewis structures.	PK limited; integration between CK and PK was weak, as teachers relied mainly on lecturing as the primary method.
2.	Octet Rule	All teachers explained the exceptions to the octet rule through lectures but did not clarify the scientific reasons behind the stability of non-octet molecules.	PK remained procedural; teaching strategies focused on rules rather than fostering conceptual reasoning
3.	Lewis Structures	All teachers taught how to draw Lewis structures by emphasizing the fulfillment of the octet rule.	PK was procedural; the strategy emphasized rule application rather than understanding molecular stability.
4.	Formal Charge	All teachers did not teach formal charge.	PK was very low; teachers did not apply strategies to help students understand this concept.

No.	Subconcept	Pedagogical Knowledge	Finding
5.	Resonance	Teachers only explained and provided examples of resonance without linking it to charge distribution within atoms.	PK was moderate; the explanation was adequate, but instructional strategies remained lecture-based.

The analysis of Pedagogical Knowledge (PK) shows that all chemistry teachers still rely on lecturing as the primary method for teaching Lewis structures. This method is chosen because it is considered efficient, but it does not effectively support students' development of conceptual reasoning[18]. This can be seen in the Lewis symbol subconcept, where teachers immediately proceeded to discuss Lewis structures without first introducing Lewis symbols, even though most teachers understood the difference between Lewis symbols and Lewis structures. However, in classroom learning, they do not explain this difference. This shows a weak integration between Content Knowledge (CK) and PK[8].

Furthermore, in the subconcepts of the octet rule and Lewis structures, teaching strategies remained procedural and centered on the application of the octet rule rather than fostering a deeper understanding of molecular stability. The concept of formal charge was not taught at all. In the subconcept of resonance, teachers only presented examples of resonant molecules without discussing the distribution of atomic charges. These findings reinforce the idea that limited general knowledge (CK) can hinder teachers' ability to design meaningful teaching strategies[7]. This is in line with previous research showing that limited content knowledge leads teachers to choose and implement inappropriate teaching approaches[9]. Therefore, strengthening content knowledge is a fundamental step to ensure that teachers are able to design effective and responsive teaching to students' needs.

The interrelation of CK, KS, and PK

PCK does not stand alone, but is formed from the mutually influencing interactions between material mastery, student understanding, and pedagogical knowledge that together determine the effectiveness of teaching[11]. Limited CK reduces teachers' awareness of student difficulties (KS), and ultimately influences the choice of learning methods (PK). Good PCK involves not only mastery of a concept, but also knowledge of how

to deliver the concept to students according to their learning needs. Studies in science education show that teachers' inability to transform conceptual knowledge into learning strategy decisions can limit their response to student misconceptions and hinder the quality of teaching [20].

The interaction between three components of PCK also influences how teachers highlight important aspects of learning content and anticipate potential student misconceptions[21]. Teachers with weak CK are often less able to recognize student misconceptions and adjust instructional strategies[13]. Limited CK tends to shift teaching towards procedural, unable to explain a concept in depth and breadth. Conversely, stronger CK allows teachers to identify learning barriers that allow students to experience misconceptions and choose more effective teaching strategies.

The interaction between CK, KS, and PK is not only interrelated but also directly determines the overall quality of teachers' PCK. Improved CK has been shown to enhance teachers' ability to interpret student responses (KS) and adjust teaching strategies (PK), allowing all three components to develop simultaneously[7]. Teachers with strong CK are able to integrate students' understanding into instructional planning, suggesting that the accuracy of KS is highly dependent on the depth of teachers' CK[8]. Therefore, teacher professional development programs should emphasize strengthening CK along with strategic reflection on how this knowledge informs students' understanding (KS) and guides the design of pedagogical strategies (PK). Such programs have been shown to help teachers transform their content knowledge into meaningful teaching practices through structured reflection and mentoring experiences[22].

CONCLUSION

This study shows that Content Knowledge (CK), student knowledge, and pedagogical

knowledge are interrelated. Teachers' limited CK in Lewis structure subconcepts, particularly the octet rule, formal charge, resonance, and molecular stability, limits their ability to identify student misconceptions and choose effective learning strategies. As a result, teaching tends to be procedural and neglects conceptual understanding. Future research should examine how targeted professional development can support the integrated development of CK, KS, and PK across a variety of chemistry topics and educational contexts.

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