Research on the Application of PBL Mode in Inorganic Chemistry Teaching: Case Analysis of Practical Teaching of Nitrogen Elements Based on Mind Maps

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Abstract

Project-based learning (PBL) is gradually gaining attention as an effective teaching method with the deepening of educational reform. The combination of thinking maps and PBL teaching mode is applied to the teaching process of nitrogen group elements, which effectively promotes the improvement of chemistry students' comprehensive skills such as creative thinking and problem solving. Students completed the PBL pre-study task list before class, and in class, teachers and students worked together to achieve the teaching objectives using the mind mapping tool. Through this new teaching model, students are able to gain a deeper understanding of the scientific principles of the nitrogen group of elements and apply what they have learned to practical problem solving. Teachers play the role of guide in this process, providing the necessary support and feedback to help students grow in their exploration. Compared with the traditional teaching mode of elementary compounds, this new teaching mode creates a more active classroom atmosphere, which fully embodies the effective teaching concept of "students as the main body, teacher as the guide".

Keywords: PBL, mind maps, elemental compounds, inorganic chemistry

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1. Introduction

The content of elemental compounds is complex and diverse, involving numerous chemical reaction equations. The properties of substances often appear similar on the surface but are actually different. In middle school, students are exposed to a limited variety of elemental compounds, while in high school, this number significantly increases (Zhu & Tang, 2023). University inorganic chemistry courses are even more comprehensive and systematic (Meng et al., 2020). Although university instructors of inorganic chemistry typically possess high academic qualifications and solid knowledge of chemistry, most college teachers lack experience in secondary education and are not sufficiently familiar with the content of high school chemistry textbooks (Fu, Wang, Xia, Li, & Zhang, 2021). This results in difficulties in effectively bridging the knowledge between secondary chemistry and inorganic chemistry during the teaching process.

In recent years, students admitted to universities come from different provinces, leading to variations in the chemistry elective modules at the high school level. This results in a disparity in students' foundational chemistry knowledge. Under traditional teaching models, the teaching of elemental compounds in university inorganic chemistry can be fragmented and complicated due to the extensive content, making it difficult for students with weak foundations to keep up with the course pace, which gradually diminishes their interest and motivation to learn (Chen et al., 2020). Therefore, teachers should conduct thorough analyses of students' learning situations when preparing lessons, pay attention to the connections between textbooks at different educational stages, and design the teaching process based on the overall level of students to avoid causing feelings of frustration, thereby improving teaching effectiveness.

This work aims to explore the effectiveness of applying the PBL (Problem-Based Learning) model in inorganic chemistry teaching, particularly through a case analysis of practical teaching on the nitrogen group elements using mind mapping tools. Before class, students complete a PBL preparation task checklist, and during class, teachers and students collaborate using the mind mapping tool to achieve the teaching objectives. The research results indicate that the PBL model can effectively enhance students' learning interest, depth of understanding, and practical skills.

2. PBL Teaching Model Based on Mind Maps

2.1 Establishment of HMS Applicability of PBL Teaching Model in Teaching Element Compounds

Compared to traditional teaching methods, the PBL approach is an effective learning method that centers on students while being guided by teachers, effectively stimulating students' initiative in learning (Ayaz & Söylemez, 2015; Zhao & Wang, 2022). Element compounds are closely related to daily life and production practices, allowing teachers to extract questions suitable for exploration and discussion. Under the guidance of teachers, implementing PBL teaching is a practical approach (Shin, Choi, Stevens, & Krajcik, 2017).

The PBL teaching method makes the learning process more exploratory and proactive (Sasson, Yehuda, & Malkinson, 2018). Students can seek solutions and answers through various means such as discussion and research, based on their own knowledge and abilities (Hanif, Wijaya, & Winarno, 2019; Santyasa, Rapi, & Sara, 2020). This method effectively reduces the pressure of classroom teaching, allowing for ample interaction between teachers and students, facilitating the resolution of questions and ultimately achieving problem-solving.

2.2 Application of Mind Maps in Teaching Element Compounds

Mind maps were created by British brain development expert Tony Buzan. They are a thinking tool and note-taking method. They link new knowledge with existing knowledge, promote systematic learning and improve memory (Budd, 2004). A major challenge is how to connect scattered and seemingly "chaotic" points of knowledge of elemental connections as nodes, to make learning of elemental connections more structured, and to achieve network connections between points of knowledge (Erdem, 2017). Mind maps can systematize knowledge and apply it to the study of elemental compounds, helping to stimulate students' interest in learning and significantly impacting on their understanding of abstract and complex issues. In addition, mind maps can further facilitate the internalization of knowledge and promote the process of PBL.

2.3 PBL Teaching Process Using Mind Maps as Medium

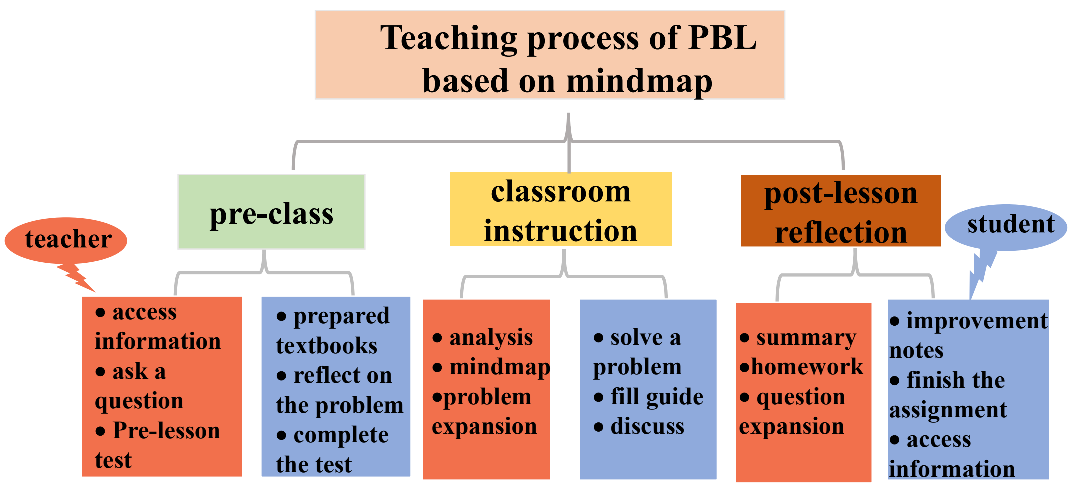

Figure 1. PBL Teaching Process Based on Mind Maps

In both new and revision classes, mind maps help learners to organise complex knowledge, integrate knowledge structures, activate knowledge and cultivate thinking skills (Davies, 2010). The PBL teaching model focuses on creating scenarios and posing problems, and when combined with mind maps to review old knowledge, it becomes an effective review method (Holmes & Hwang, 2016; Santyasa et al., 2020). Implementing PBL teaching with mind maps can achieve effective links between high school and university chemistry, reduce learning difficulties, stimulate students' interest and promote deep learning (Figure 1). The PBL teaching model is widely used in learning chemical reaction principles and material structures, where learning groups establish good cooperation patterns, and students gradually develop habits of self-study and active participation in discussions (Ayyildiz & Tarhan, 2017; Barak & Dori, 2005). The characteristics of the mind map-based PBL teaching process include thorough preparation before class, guiding students from problem identification to problem solving during class using mind maps, and allowing students to design personalized mind maps after class based on their individual characteristics, covering topics such as the properties, preparation and uses of chalcogen elements (Hidayati, Zubaidah, & Amnah, 2023).

3. PBL Teaching Model Based on Mind Maps

3.1 Analysis of Teaching Materials and Student Learning Situations: Designing Pre-Class Reflection Questions

This work takes the nitrogen group elements in the elemental compounds section of the Inorganic Chemistry textbook published by the Inorganic Chemistry Teaching and Research Department of Dalian University of Technology as an example of teaching design. In both middle school and high school, students are exposed to content related to nitrogen, phosphorus and their compounds. The elements of the nitrogen group are introduced in the elements (II) section of the p section of the textbook of inorganic chemistry, which mainly covers five elements, namely nitrogen, phosphorus, arsenic, antimony and bismuth, with emphasis on discussing the existence, preparation, properties and uses of the monomers of nitrogen and phosphorus, as well as their compounds, etc. Compared with secondary school chemistry, the section on nitrogen has new content, such as ammonia and oxides of nitrogen, while the section on phosphorus has more content, including phosphine, phosphides, oxides of phosphorus and their acids (e.g. phosphoric acid and its salts, phosphite and its salts, etc.). According to the content of the textbook and the knowledge base of the students, a list of tasks for independent learning will be designed before the lesson. Teachers need to carefully prepare lessons before class, fully understand the students' situation and design high quality pre-learning task sheets. Adequate guidance is provided through online communication platforms such as cloud classroom, QQ and Wechat to ensure that students complete the pre-learning tasks carefully, thus laying a solid foundation for the smooth implementation of PBL teaching in the subsequent class.

3.2 Design Mind Maps using Questions to Guide Student Discussion and Problem Solving in the Classroom

A mind map for the PBL classroom is designed based on the students' completed guided learning programmed collected before the class, combined with the questions raised by the students in the pre-test (Faradilla, Afrida, & Pramono, 2024; Ravindranath, Abrew, & Nadarajah, 2016). In the classroom, the teacher will give lectures while guiding the students to gradually fill in and improve the mind map. Pre-prepared problems will be interspersed in the teaching process to encourage students to think independently and discuss in groups to solve problems together. In order to increase the effectiveness of classroom teaching and stimulate students' participation, questions should be set according to the principle of from simple to complex, from shallow to deep. Teachers should set aside 10 minutes for students to complete the online test in class. This test can not only encourage students to listen carefully and participate in discussion, but also effectively collect data on the teaching effect under this teaching mode. In addition, classroom teaching should also expand on problems closely related to life and production. For example, when explaining the properties and uses of phosphorus monomers, the latest research progress of black phosphorus nanosheets and their application prospects can be further introduced. After the lesson, the Cloud Classroom Resource Library will provide relevant literature for students to read, and some reflection questions will be set to promote deeper understanding.

3.3 Post-Lesson Reflection and In-Depth Discussion of Mind Mapping: Collecting and Assessing Students' Mind Mapping Work

Teaching evaluation is an important part of classroom teaching (Martinez, Taut, & Schaaf, 2016), and effective evaluation of 'teaching' and 'learning' can optimise the application of the mind-mapping PBL teaching model in inorganic chemistry. Students evaluate the pre-study task list provided by the teacher, including content, feasibility and difficulty. Teachers set up online questionnaires through Cloud Class after each lesson to collect and analyse the results to optimise the PBL teaching design and reflect the teaching-learning process. Teachers' evaluation not only confirms students' learning ability, but also stimulates their active learning. The comprehensive evaluation of the PBL teaching model based on mind mapping includes both qualitative and quantitative aspects (Budd, 2004; Chang & Lee, 2010). Qualitative evaluation indicators include whether students ask valuable questions before class, participate in online discussions, fill in mind maps in class, perform in group discussions, and reflect on notes and mind map design after class. Quantitative evaluation is based on students' pre-course tests, classroom tests and post-course homework completion.

4. Conclusion

The integration of mind mapping and PBL in the teaching of nitrogen group elements has been demonstrated to markedly enhance the development of students' comprehensive abilities in creative thinking and problem-solving. This innovative teaching method has been observed to enhance students' interest in learning and to strengthen their sense of active learning. Prior to the commencement of the course, students were obliged to complete a series of pre-study tasks aligned with the PBL approach. This process requires students to engage in independent learning and critical thinking about the relevant knowledge of the nitrogen group elements in advance, in order to prepare for the class discussion. In this manner, students were able to cultivate an initial comprehension of the subject matter prior to the class, thereby facilitating their active participation in discussions and collaborative endeavors within the classroom setting. In the classroom setting, the mind map serves as the primary pedagogical tool, with teachers and students working collaboratively to accomplish the teaching task. The use of thinking maps facilitates the clarification of students' knowledge structures, while also fostering interaction and communication between them. In this pedagogical approach, students are afforded the opportunity to engage in a comprehensive exploration of the properties and reactions of oxygen group elements, as well as their applications in real-life scenarios, through group discussion and problem-solving. In comparison with the conventional approach to teaching elemental compounds, this pedagogical approach, which combines mind mapping and PBL, markedly enhances the classroom ambience, rendering it more dynamic and interactive. Furthermore, students are able to gain a deeper comprehension of the subject matter and develop essential literacy skills, including teamwork, critical thinking, and creativity. This effective "student-led, teacher-led" teaching model exemplifies the fundamental principles of modern educational philosophy, which emphasizes student-driven exploration and discovery, the advancement of students' comprehensive abilities, and the establishment of a robust foundation for lifelong learning.

There is a significant difference between university and secondary education. University learning is not limited to the classroom, especially in the learning of elementary compounds, where classroom teaching can only cover the important laws and key contents, but cannot explain them in a comprehensive and detailed manner. The role of university teachers is not only to impart knowledge and skills, but also to pay attention to the teaching process, methodological guidance and the cultivation of emotions and values. Classroom design should take into account the hierarchy of problem situations and encourage students to take the initiative in analysing and solving problems and in asking new questions. Cultivating problem analysis and problem solving skills will help students to quickly identify the knowledge and skills required for work after graduation, to assess their own mastery and to compensate for deficiencies by appropriate means, so that they can adapt to a wide range of disciplines and occupations.

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